BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

REPORT

OF THE

NINETY-SECOND MEETING

(NINETY-FOURTH YEAR)

TORONTO—1924

AUGUST 6–13

LONDON

OFFICE OF THE BRITISH ASSOCIATION
BURLINGTON HOUSE, LONDON, W.1

1925

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TABLE OF

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[*Continued on p.* xii.

ANNUAL MEETINGS.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting

[*Continued on p.* xiii.

Table of

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S. ...	267	13
1901, Sept. 11	Glasgow..................	Prof. A. W. Rücker, D.Sc., Sec.R.S. ...	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17......	Cambridge...............	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15......	South Africa	Prof. G. H. Darwin, LL.D., F.R.S. ...	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25......	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield..................	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S................	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S................	376	40
1914, July-Sept....	Australia	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S.	242	19
1916, Sept. 5	Newcastle-on Tyne...	Sir Arthur Evans, F.R.S.	164	12
1917	(No Meeting)		—	—
1918	(No Meeting)		—	—
1919, Sept. 9	Bournemouth	Hon. Sir C. Parsons, K.C.B., F.R.S....	235	47
1920, Aug. 24......	Cardiff	Prof. W. A. Herdman, C.B.E., F.R.S.	288	11
1921, Sept. 7	Edinburgh	Sir T. E. Thorpe, C.B., F.R.S.	336	9
1922, Sept. 6	Hull	Sir C. S. Sherrington, G.B.E., Pres. R.S.	228	13
1923, Sept. 12	Liverpool	Sir Ernest Rutherford, F.R.S.	326	12
1924, Aug. 6	Toronto	Sir David Bruce, K.C.B., F.R.S.......	119	7

Annual Meetings—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
297	45	801	482	9	1915	£1801 0	£1072 10 0	1900
374	131	794	246	20	1912	2046 0	920 9 11	1901
314	86	647	305	6	1620	1644 0	947 0 0	1902
319	90	688	365	21	1754	1762 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0	887 18 11	1904
937[1]	411	430	181	16	2130	2422 0	928 2 2	1905
356	93	817	352	22	1972	1811 0	882 0 9	1906
339	61	659	251	42	1647	1561 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0	1157 18 8	1908
290[2]	162	789	90	7	1468	1623 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0	963 17 0	1910
349	61	414	81	31	1241	1176 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0	978 17 1	1913
139	4160[3]	539[3]	—	21	5044[3]	4873 0	1861 16 4[6]	1914
287	116	628[4]	141	8	1441	1406 0	1569 2 8	1915
250	76	251[4]	73	—	826	821 0	985 18 10	1916
—	—	—	—	—	—	—	677 17 2	1917
—	—	—	—	—	—	—	326 13 3	1918
254	102	688[4]	153	3	1482	1736 0	410 0 0	1919

Old Annual Regular Members	Annual Members		Transferable Tickets	Students' Tickets					
	Meeting and Report	Meeting only							
136	192	571	42	120	20	1380	1272 10	1251 13 0[8]	1920
133	410	1394	121	343	22	2768	2599 15	518 1 10	1921
90	294	757	89	235[5]	24	1730	1699 5	772 0 7	1922
					Complimentary.				
123	380	1434	163	550	308[7]	3296	2735 15	777 18 6[9]	1923
37	520	1866	41	89	139	2818	3165 19[10]	1197 5 9	1924

[1] Including 848 Members of the South African Association.

[2] Including 137 Members of the American Association.

[3] Special arrangements were made for Members and Associates joining locally in Australia, see Report, 1914, p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.

[4] Including Students' Tickets, 10*s*.

[5] Including Exhibitioners granted tickets without charge.

[6] Including grants from the Caird Fund in this and subsequent years.

[7] Including Foreign Guests, Exhibitioners, and others.

[8] The Bournemouth Fund for Research, initiated by Sir C. Parsons, enabled grants on account of scientific purposes to be maintained.

[9] Including grants from the Caird Gift for research in radioactivity in this and subsequent years.

[10] Subscriptions paid in Canada were $5 for Meeting only and others pro rata; there was some gain on exchange.

REPORT OF THE COUNCIL, 1923–24.

I. Professor Horace Lamb, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for the year 1925-26 (Southampton Meeting).

II. The Council have passed resolutions of regret at the death of Prof. T. G. Bonney, F.R.S. (Secretary, 1881-85; President, 1910), Sir Edmund Walker, Chancellor of the University of Toronto and Vice-President elect of the Association for the Toronto Meeting, and Sir William Herdman, C.B.E., F.R.S. (General Secretary, 1903-19; President, 1920).

III. The General Officers, a Committee of the Council, and the Council themselves, have been fully occupied with arrangements for the Toronto Meeting. They acknowledge gratefully the unsparing labours of the executive in Toronto, with which the Secretary of the Association was enabled to acquaint himself during a visit, on the invitation of the executive, to Toronto in January. They have also to acknowledge the generosity of the American Association for the Advancement of Science in undertaking to distribute circulars relating to the Meeting to all its members.

IV. Representatives of the Association have been appointed as follows:

Physical Society of France, Fiftieth Anniversary	Professor F. Lindemann.
Royal Colonial Institute, Committee dealing with conference on questions of imperial education at the British Empire Exhibition	Professor T. P. Nunn.
American Association for the Advancement of Science, Cincinnati Meeting	Professor J. P. MacMurrich.
Kelvin Centenary, Committee of Honour	Sir Ernest Rutherford.
British Academy, Committee on reparation of losses to Imperial University Library, Tokyo, through earthquake†	Professor J. L. Myres.
Joseph Leidy Commemorative Meeting, Philadelphia	Professor W. H. Welch.
International Mathematical Congress, Toronto	Sir William Ashley, Sir William Bragg, Professor G. W. O. Howe, Major P. A. MacMahon.
Franklin Institute, Centenary Celebration	Sir Ernest Rutherford and Hon. Sir Charles Parsons.
Association Française pour l'Avancement des Sciences, Liége Meeting	Dr. J. G. Garson.

Sir R. A. Gregory, who was appointed to represent the Association on the Cinematograph Committee of the Board of Education, reports that the Committee has been informed of the importance attached to its work by the President of the Board, who is publishing its results as part of the Imperial Education Conference.

† A set of the Association Reports, so far as available, has been presented to the Library.

V. Resolutions referred by the General Committee at the Liverpool Meeting to the Council for consideration, and, if desirable, for action, were dealt with as follows :—

(*a*) Following upon resolutions received from all Sections excepting Section F, and from the Conference of Delegates of Corresponding Societies, regarding the provision of more adequate accommodation for the Science Museum, South Kensington, the Council addressed the following on the subject: The First Lord of the Treasury, the Lord President of the Council, the First Lord of the Admiralty, the Secretary of State for War, the Minister for Air, the President of the Board of Education, the First Commissioner of Works, the Minister of Health, the President of the Board of Trade, the Secretary for Mines, the Parliamentary Secretary to the Office of Works and Transport (Board of Trade), the Postmaster-General, the Minister of Agriculture and Fisheries.

(*b*) Following upon resolutions from several Sections and the Conference of Delegates, dealing with the need for more adequate protection of sites of scientific and historical interest, the Council addressed the appropriate Government Departments, and summoned a conference at which H.M. Office of Works and the following societies and institutions were represented : The Royal Anthropological Institute, the Congress of Archæological Societies, the Architectural Association, the Folklore Society, the Royal Geographical Society, the Geological Society, the Geologists' Association, the Linnean Society, the National Trust, the British Ornithologists' Union, the Society for the Protection of Ancient Buildings, the Society for the Promotion of Roman Studies, and the Zoological Society. The chair was taken by the Rt. Hon. the Earl of Crawford and Balcarres. No resolution was formulated, but the discussion in general revealed cordial agreement with the suggestion contained in the letter summoning the conference, that the sole effective remedy appears to be that learned societies not immediately concerned in a particular problem of conservation should take concerted steps to promote legislation wider in scope and more strictly worded than the Ancient Monuments Act now in force for the protection of such sites.

(*c*) Following upon resolutions from several Sections and the Conference of Delegates, a letter dealing with the suspension of the sale of quarter-sheets of the 6-in. Ordnance Map was addressed to the Director-General of the Ordnance Survey, who courteously informed the Council of the reasons which had rendered this step necessary.

(*d*) The Council gave effect to resolutions dealing with the publication of the reports of Committees on Geographical Teaching and on Complex Stress Distribution in Engineering Materials ; and approved proposals as to the destination of ' finds ' from the excavations at Avebury.

(*e*) The Council approved the following resolutions from the Conference of Delegates of Corresponding Societies :—

To recommend that the publications of scientific societies should conform so far as possible to a standard size of page for convenience in dealing with off-prints ; and that for octavo publications the size of the British Association's Report be adopted as the standard.

To urge the adoption by scientific societies of the bibliographical recommendations contained in the current Report of the Zoological Publications Committee.

To call the attention of local scientific societies to the need for prompt and systematic supervision, in the interests of scientific record, of all sections and other excavations which are opened during the construction of new roads or other public works.

A resolution dealing with the metric gallon was referred to the Organising Committees of Sections A and G, with a view to further discussion at the Annual Meeting.

(*f*) A resolution received from the Committee on Marine Biological Research in India through the Organising Committee of Section D, dealing with further provision for such research in Indian waters and the establishment of a station in the Andaman Islands, was submitted to H.M. Secretary of State for India, with a request for his sympathetic consideration, and has been forwarded by him to the Government of India.

VI. The Council have received reports from the General Treasurer throughout the year. His accounts have been audited and are presented to the General Committee.

The Council made the following grants to research committees from the Caird Fund :—

Seismology Committee	£100
Naples Table Committee	100
Bronze Implements Committee	60
Tables of Constants Committee	15
Zoological Record Committee	50
Plymouth Marine Laboratory Committee... ...	25

The third grant of £250 from the Caird Gift for research in radioactivity (for the year ending March 24, 1925) has been divided between Messrs. C. T. R. Wilson, A. S. Russell, and J. Chadwick.

The British Association Exhibitions established in connection with the Liverpool Meeting were awarded to nineteen students nominated by the same number of universities and colleges, while six of these institutions made equivalent allowances for thirteen additional students. All were entertained by the Local Executive Committee at Liverpool. The fact that the forthcoming meeting will be overseas obviously prohibits the full maintenance of the scheme for the present year, but the Council are glad to report that certain institutions are assisting students or members of junior staffs to attend, and it has been found possible to offer some assistance from Association funds, while the local executive at Toronto has generously promised hospitality.

At the meeting of the Council in December last the General Treasurer made the following statement :—

It will be within the recollection of the Council that Sir Charles Parsons, when President at the Bournemouth Meeting in 1919, initiated a fund to enable the Association to maintain its grants for research. A measure of support for research had been given during the two years 1917-18, in spite of the fact that there were no meetings of the Association, in consequence of which its resources were seriously depleted. The fund was initiated to cover the deficit for those years as well as to assist the Association for the future. Ordinary working expenses were at the time exceeding receipts, especially in the direction of printing, despite the strict economies put into force by the Council.

About the same time as the Bournemouth fund was initiated, the Department of Scientific and Industrial Research made a grant of £600 to the Association, specifying certain researches (within the scope of the Department) to which this sum might be

specifically devoted, and requiring an annual statement of the expenditure. This account has recently been closed, and the moment is therefore opportune to summarise the whole position in relation to these generous gifts to the Association. The sum expended by the Association on research in the period 1917-23, excluding grants made at the recent meeting in Liverpool, has been £4,306. The sum received on account of the Bournemouth fund was £2,038, and this, together with the grant from the Research Department and the gifts of the late Sir James Caird, has enabled the Association still to meet the demands of research, while continuing to discharge its ordinary liabilities (greatly as these have increased since the war) and even in some measure extending them, as notably in the case of the 'exhibitions' awarded in recent years to selected science students toward their expenses in attending annual meetings.

It is only right to conclude this statement with reiterated thanks to the donors of the Bournemouth fund who so generously helped the Association over a critical period; in particular the principal contributors, Sir Charles Parsons (£1,000), Sir Alfred Yarrow (£500), Sir R. Hadfield (£250), Sir Hugh Bell (£100), Sir William Herdman (£100). Such generosity encourages those responsible for the financial affairs of the Association to aim at establishing for it a fuller measure of financial independence in relation to its ordinary expenditure, and especially that incurred at the annual meetings, and ensuring that a fuller proportion of the sums received by way of membership subscription may be available for the direct support of scientific work.

VII. The Council have to thank the Museums Association for its invitation to hold the Conference of Delegates of Corresponding Societies at Wembley in connexion with the Association's meeting there in July. Professor J. L. Myres has been nominated as President of the Conference.

The Corresponding Societies Committee has been nominated as follows: The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), the General Treasurer, the General Secretaries, Dr. F. A. Bather, Mr. O. G. S. Crawford, Prof. P. F. Kendall, Mr. Mark L. Sykes, Dr. C. Tierney, Prof. W. W. Watts, Mr. W. Whitaker.

VIII. The retiring Ordinary Members of the Council are: Sir R. A. Gregory, Mr. J. H. Jeans, Sir A. Keith, Mr. W. Whitaker, and Dr. W. E. Hoyle.

The Council have received with sincere regret the resignation of Dr. W E. Hoyle owing to ill-health.

The Council nominate the following new members:—

Principal Ernest Barker | Prof. E. G. Coker
Sir T. H. Holland

leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of Ordinary Members is as follows:—

Dr. F. W. Aston.	Prof. A. Fowler.
Mr. J. Barcroft.	Sir Daniel Hall.
Principal E. Barker.	Mr. C. T. Heycock.
Sir W. H. Beveridge.	Sir T. H. Holland.
Rt. Hon. Lord Bledisloe.	Sir J. Scott Keltie.
Prof. E. G. Coker.	Prof. A. W. Kirkaldy.
Prof. W. Dalby.	Dr. P. Chalmers Mitchell.
Prof. C. H. Desch.	Dr. C. S. Myers.
Mr. E. N. Fallaize.	Prof. A. W. Porter.
Dr. J. S. Flett.	Prof. A. C. Seward.
Prof. H. J. Fleure.	Prof. A. Smithells.
	Mr. A. G. Tansley.

IX. The General Officers have been nominated by the Council as follows :—

General Treasurer: Dr. E. H. Griffiths.

General Secretaries: Prof. J. L. Myres, Mr. F. E. Smith.

X. The following have been admitted as members of the General Committee :—

Mr. L. L. Belinfante.	Prof. E. H. Neville.
Mr. D. Ward Cutler.	Mr. H. J. Page.

Dr. G. H. Vevers.

XI. The Council have put into operation for the Toronto Meeting the following alteration of practice in regard to eligibility for Students' Tickets, and recommend the same as a change in the Rules :—

To substitute for Sections (iii) (iv) of Rule X, 2 :—

(iii) Persons not exceeding 23 years of age, being students of universities or of any educational institution recognised by the Local Executive Committee or the General Officers of the Association, may obtain 'students' tickets' for the meeting on payment of 10s. Holders of such tickets shall not be entitled to any privilege beyond attendance at the Annual Meeting.

BRITISH ASSOCIATION EXHIBITIONS.

Owing to distance and expense, it was not possible to assist the usual number of selected science students to attend the Meeting from Britain. Five students, however, were enabled to do this by the co-operation of King's College, London, University College, Cardiff, University College, Exeter, and the Local Committee in Toronto, and with assistance from the funds of the Association.

GENERAL MEETINGS, ETC., IN TORONTO.

Inaugural General Meeting.

The Inaugural General Meeting took place in Convocation Hall, University of Toronto, on Wednesday, August 6, at 8.30 p.m.

Sir Ernest Rutherford, F.R.S., read the following letter from H.R.H. The Prince of Wales, K.G., F.R.S. :—

St. James's Palace, S.W.1.
July 3, 1924.

Dear Mr. President,—Will you be good enough to convey to the members of the British Association at their inaugural meeting in Toronto my cordial good wishes for a very successful session ?

My knowledge of Canada assures me that your visit will be warmly welcomed, and that nothing but good can come of such a gathering, where the representatives of the most advanced thought from the old country will meet in discussion the equally keen and active intellects of the younger land.

My interest has been particularly arrested by one item that is to come up for discussion, namely, the educational training of boys and girls in this country for life overseas. The call of the Empire for a wider distribution of the home population, for men and women to open up the vast uncultivated areas in the great overseas dominions, is more imperative to-day than at any time in its history.

I congratulate the Association on thus showing in its deliberations such a broad interest in these problems, and I trust, and indeed am confident, that the influence thus exercised may result in great and extended benefits to the Empire.—Yours truly,

EDWARD P.

The President of the British Association.

To this gracious message the following reply was telegraphed from the meeting :—

H.R.H. The Prince of Wales, St. James's Palace, London.

British Association for Advancement of Science at inaugural meeting, Toronto, August 6, begs leave humbly to thank Your Royal Highness for gracious message, which enhances our hope and belief that substantial benefits to cause of science will accrue from this meeting of scientific workers from Britain, Canada and America. Your Royal Highness's personal interest in educational training of boys and girls for life overseas is especially appreciated.

Ernest Rutherford, *President.*

The Association was welcomed to Toronto by Sir Robert Falconer, K.C.M.G., President of the University of Toronto, on behalf of the University; by Prof. J. C. Fields, F.R.S., President of the Royal Canadian Institute, on behalf of that body; and by the Hon. Forbes Godfrey, Minister of Health, on behalf of the Government of the Province of Ontario.

Sir Ernest Rutherford, F.R.S., resigned the office of President of the Association to Major-General Sir David Bruce, K.C.B., F.R.S., who delivered an address on Prevention of Disease (for which see p. 1).

Evening Discourses.

Sir Thomas Holland, K.C.M.G., F.R.S. : 'The Formation and Destruction of Mineral Deposits.' 8.30 p.m., August 8, Convocation Hall.

Professor D'Arcy Wentworth Thompson, C.B., F.R.S. : 'The Shell of the Nautilus.' 8.30 p.m., August 11, Convocation Hall.

Citizens' Lectures.

Sir Henry Fowler, K.B.E. : 'Metallurgy and its Influence on Social Life.' 8 p.m., Thursday, August 7, Assembly Hall, Jarvis Collegiate Institute.

J. S. Huxley, M.A. : 'Control of Growth.' 8 p.m., Friday, August 8, University of Toronto Schools.

Professor A. S. Eddington, F.R.S. : 'Einstein's Theory of Relativity.' 8 p.m., Saturday, August 9, Convocation Hall.

Sir R. Robertson, M.A., F.R.S. : 'Explosives' (with experiments). 8 p.m., Monday, August 11, Assembly Hall, Oakwood Collegiate Institute.

Professor E. P. Cathcart, C.B.E. : 'Seeing is Believing.' 8 p.m., Tuesday, August 12, Assembly Hall, University of Toronto Schools.

Children's Lectures.

Sir W. Bragg, K.B.E., D.Sc., F.R.S. : 'Diamond and Black Lead.' 4 p.m., Friday, August 8, Convocation Hall.

Professor J. H. Priestley, D.S.O. : 'Plant Waterproofs.' 3.30 p.m., Monday, August 11, Lecture Hall, Physics Building, University of Toronto.

Captain L. H. Dudley Buxton : 'Beyond the Great Wall of China and the People who live there.' 3 p.m., Tuesday, August 12, Assembly Hall, Central Technical School.

Scientific Exhibition.

An Exhibition of scientific instruments, apparatus, and books was opened in the University throughout the Meeting.

Concluding General Meeting.

The Concluding General Meeting was held in Convocation Hall on Wednesday, August 13, at 5.30 p.m., when the following Resolutions were adopted with acclamation :—

1. The British Association for the Advancement of Science most warmly thanks the University of Toronto and the Royal Canadian Institute for the invitation which has led to the brilliant Meeting now concluding; and in particular to the University for placing at the disposal of the Association its meeting-rooms, residences, and other resources. Gratitude is also due to the Governments of the Dominion and of the Province of Ontario, the City of Toronto, and private donors, for their generous contribution of funds toward the expenses of the Meeting. Those of the members who are about to take part in the Western Excursion have further to express their obligation to the Western Provinces which have contributed toward the cost of the excursion. The best thanks of the Association are due to members of the University faculty, the staff, and others, who have laboured unsparingly in the organisation of the Meeting; and it has also to acknowledge the generous hospitality of numerous institutions and individuals. The large attendance of citizens, whose presence has so greatly contributed to the success of the Meetings, is deeply appreciated; as also are the able support afforded by the Press and the unfailing assistance of transport companies and other authorities.

2. The best thanks of the British Association are accorded to the American Association for the Advancement of Science for its cordial and effective co-operation.[1]

After the above Resolutions had been proposed and answered, the President brought the Meeting to a conclusion with an expression of thanks to Canada.

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[1] The American Association distributed some 17,000 of the British Association's circulars to its members and those of societies in correspondence with it, and took every possible measure to ensure a large and representative attendance of American men of science at the Toronto Meeting. It was resolved that Members of the American Association taking the $5 ticket for the Meeting should receive the Report, if desired, without further charge.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

GENERAL TREASURER'S ACCOUNT

JULY 1, 1923, TO JUNE 30, 1924.

(NOTE.—An increase which will be observed in the cost of printing is accounted for by the facts that the Report for 1923 was larger, and the number required larger, than in 1922. Preparations for a meeting overseas in 1924 further necessitated increased printing of programmes, and larger expenditure on postage and stationery.)

Balance Sheet,

LIABILITIES.

	£ s. d.	£ s. d.
To Capital Accounts—		
General Fund, as per contra		10,575 15 2
(Subject to Depreciation in Value of Investments)		
" Caird Fund—		
As per contra		9,582 16 3
(Subject to Depreciation in Value of Investments)		
" Caird Fund—		
Revenue Account, Balance as at July 1, 1923	687 2 4	
Add Excess of Income over Expenditure for the year	44 7 0	
		731 9 4
" Caird Gift, Radio-Activity Investigation—		
Balance at July 1, 1923	857 19 5	
Add Dividends on Treasury Bonds	20 16 0	
Income Tax Recovered	10 15 0	
Profit on Sale of Treasury Bonds	42 18 11	
	932 9 4	
Less Grants Paid	350 0 0	
		582 9 4
" Sir F. Bramwell's Gift for Enquiry into Prime Movers, 1931—		
£50 Consols accumulated to June 30, 1924, as per contra		59 10 0
" Sir Charles Parson's Gift		10,000 0 0
" John Perry Guest Fund—		
For cases of emergency connected with Guests of the Association		75 0 0
" Life Compositions as at July 1, 1923	285 0 0	
Add Received during year	225 0 0	
		510 0 0
" Legacy, T. W. Backhouse		450 0 0
" Sundry Creditors	81 16 0	
" Income and Expenditure Account—		
Balance at July 1, 1923	2,958 19 0	
Add Excess of Income over Expenditure for the year	855 12 2	
		3,896 7 2
		£36,463 7 3

I have examined the foregoing Account with the Books and Vouchers and certify the same

Approved,
ARTHUR L. BOWLEY } *Auditors.*
A. W. KIRKALDY

July 11, 1924.

June 30, 1924.

ASSETS.

		£ s. d.	£ s. d.
By Investments on Capital Accounts—General Fund—			
£4,651 10*s.* 5*d.* Consolidated 2½ per cent. Stock at cost		3,942 3 3	
£3,600 India 3 per cent. Stock at cost		3,522 2 6	
£879 14*s.* 9*d.* £43 Great Indian Peninsula Railway "B" Annuity at cost		827 15 0	
£52 12*s.* 7*d.* War Stock (Post Office Issue) at cost		54 5 2	
£810 10*s.* 3*d.* War Stock converted to £834 16*s.* 6*d.* 4½ per cent. Conversion Loan at cost		835 12 4	
£1,400 War Loan Bonds 5 per cent. at cost		1,393 16 11	
			10,575 15 2
Value at date, £6,321 10*s.* 10*d.*			
,, Caird Fund—			
£2,627 0*s.* 10*d.* India 3½ per cent. Stock at cost		2,400 13 3	
£2,100 London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock at cost		2,190 4 3	
£2,500 Canada 3½ per cent. 1930/50 Registered Stock at cost		2,397 1 6	
£2,000 Southern Railway Consolidated 5 per cent. Preference Stock at cost		2,594 17 3	
			9,582 16 3
Value at date, £7,502 19*s.* 7*d.*			
,, Caird Fund Revenue Account— Cash at Bank			731 9 4
,, Caird Gift—			
£400 Registered Treasury Bonds		400 0 0	
Cash at Bank		182 9 4	
			582 9 4
,, Sir F. Bramwell's Gift—			
£116 8 6 2½ per cent. Self-Accumulating Consolidated Stock as per last Balance Sheet		56 11 0	
5 2 0 *Add* Accumulations to June 30, 1924		2 19 0	
£121 10 6			59 10 0
Value at date, £69 5*s.* 4*d.*			
,, Sir Charles Parson's Gift—			
£10,000 5 per cent. War Loan converted to £10,300 4½ per cent. Conversion Stock at cost			10,000 0 0
Value at date, £10,068 5*s.* 0*d.*			
,, John Perry Guest Fund—			
£96 National Savings Certificates at cost		74 8 0	
Cash at Bank		0 12 0	
			75 0 0
,, Life Compositions—			
£649 3*s.* 4*d.* Local Loans at cost		420 0 0	
Cash at Bank		90 0 0	
			510 0 0
,, Legacy—T. W. Backhouse— Cash at Bank			450 0 0
,, Revenue Account—			
£2,098 1*s.* 9*d.* Consolidated 2½ per cent. Stock at cost.		1,200 0 0	
£1,500 Registered Treasury Bonds at cost		1,500 0 0	
Sundry Debtors		233 15 4	
Cash at Bank	1,408 0 11		
Cash on Deposit	1,000 0 0		
Cash in Hand	9 1 7		
	2,417 2 6		
Less as shown above—			
Caird Fund Revenue Account 731 9 4			
Caird Gift 182 9 4			
John Perry Guest Fund 0 12 0			
Life Compositions 90 0 0			
Legacy—T. W. Backhouse 450 0 0	1,454 10 8		
		962 11 10	
			3,896 7 2
			£36,463 7 3

to be correct. I have also verified the Balances at the Bankers and the Investments.

W. B. KEEN,
Chartered Accountant.

Income and

FOR THE YEAR

EXPENDITURE.

1923 £ s. d.		£ s. d.	£ s. d.
14 12 1	To Heat and Lighting	14 7 8	
47 4 5	,, Stationery	68 10 10	
16 0 0	,, Rent	1 0 0	
150 1 5	,, Postages	225 7 7	
185 5 6	,, Travelling Expenses	113 14 0	
50 5 6	,, Exhibitioners	27 14 10	
201 16 10	,, General Expenses	177 0 9	
665 5 9		627 15 8	
1,108 5 0	,, Salaries and Wages	1,130 9 1	
75 0 0	,, Pension Contribution	75 0 0	
1,396 3 6	,, Printing, Binding, etc.	1,851 7 8	
			3,684 12 5
	,, Sir Robert Hadfield's Gift—		
50 0 0	Grants to Universities		50 0 0
	,, Grants to Research Committees—		
	Index Kewensis Committee	60 0 0	
	Old Red Sandstone of the Bristol District Committee	20 0 0	
	Corresponding Societies Committee	40 0 0	
	Growth of Children Committee	20 0 0	
	Parthenogenesis Committee	5 0 0	
	Colloid Chemistry Committee	5 0 0	
	Stress Distributions Committee	9 10 1	
	Overseas Training Committee	5 0 0	
	Pre-Cambrian Rocks Committee	30 0 0	
	Marine Algæ Committee	25 0 0	
	Muscular Stiffness Committee	25 0 0	
	Auxiliary Language Committee	3 0 0	
	Characteristic Fossils Committee	5 0 0	
	Lower Carboniferous Committee	10 0 0	
	Quaternary Peats Committee	50 0 0	
	Cost of Cycling Committee	50 0 0	
	Botanical Survey of Sherwood Forest Committee	20 0 0	
	Population Map Committee	5 0 0	
	Glacial Deposits Committee	30 0 0	
	Derbyshire Caves Committee	8 15 8	
	Tertiary Rocks Committee	15 0 0	
	Old Red Sandstone Rocks of Kiltorcan, Ireland, Committee	15 0 0	
	Zoological Bibliography Committee	1 0 0	
	Bronze Age Implements Committee	40 0 0	
257 18 6			497 5 9
336 19 9	,, Balance, being Excess of Income over Expenditure for the year		855 12 2
3,889 12 6			£5,087 10 4

Caird

EXPENDITURE

£ s. d.		£ s. d.	£ s. d.
	To Grants Paid—		
	Tables of Constants Committee	15 0 0	
	Plymouth Station Committee	25 0 0	
	Naples Station Committee	100 0 0	
	Bronze Age Implements Committee	60 0 0	
	Zoological Record Committee	50 0 0	
	Seismological Investigations Committee	100 0 0	
270 0 0			350 0 0
113 10 4	,, Balance, being Excess of Income over Expenditure for the year		44 7 0
£383 10 4			£394 7 0

Expenditure Account

ENDED JUNE 30, 1924.

INCOME.

1923 £	s.	d.				£	s.	d.	£	s.	d.
307	0	0	By Annual Members (Including £87 10*s.* 0*d.*, 1924/25)						276	10	0
846	0	0	,, Annual Members, Temporary (Including £327, 1924/25)						1,680	0	0
477	0	0	,, Annual Members, with Report (Including £133 10*s.*, 1924/25)						649	10	0
106	5	0	,, Transferable Tickets (Including £2 10*s.*, 1924/25)						217	10	0
109	10	0	,, Students' Tickets (Including £3 10*s.*, 1924/25)						281	0	0
			,, Life Members' additional Subscriptions						10	0	0
10	10	0	,, Donations						6	1	9
10	17	3	,, Interest on Deposits						34	14	10
60	12	9	,, Advertisements						138	5	2
802	8	0	,, Sales of Publications						659	12	10
50	0	0	,, Sir Robert Hadfield's Gift						50	0	0
111	12	1	,, Unexpended Balance of Grants returned						3	5	3
117	15	6	,, Income Tax Recovered						98	3	4
			,, Dividends—								
			116 14 4	Consols		168	14	8			
			81 0 0	India 3 per cent.		108	0	0			
			24 19 4	Great Indian Peninsula "B" Annuity		25	13	3			
			96 10 6	War Stock		97	8	0			
			500 0 0	War Stock, Sir Charles Parson's Gift		500	0	0			
			59 1 3	Treasury Bonds		73	12	6			
			1 16 6	Local Loans		9	8	9			
880	1	11							982	17	2
3,889	12	6							£5,087	10	4

Fund.

INCOME.

£	s.	d.		£	s.	d.	£	s.	d.
			By Dividends on Investments—						
			India 3½ per cent.	91	18	8			
			Canada 3½ per cent.	67	16	2			
			London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock	64	11	6			
			Southern Railway Consolidated 5 per cent. Preference Stock	76	17	6			
270	5	6					301	3	10
113	4	10	,, Income Tax Recovered				93	3	2
£383	10	4					£394	7	0

RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN TORONTO: AUGUST, 1924.

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICS AND PHYSICS.

Seismological Investigations.—Prof. H. H. Turner (*Chairman*), Mr. J. J. Shaw (*Secretary*), Mr. C. Vernon Boys, Dr. J. E. Crombie, Dr. C. Davison, Sir F. W. Dyson, Sir R. T. Glazebrook, Prof. H. Lamb, Sir J. Larmor, Prof. A. E. H. Love, Prof. H. M. Macdonald, Prof. H. C. Plummer, Mr. W. E. Plummer, Prof. R. A. Sampson, Sir A. Schuster, Sir Napier Shaw, Dr. G. T. Walker. **£100** (Caird Fund grant).

Tides.—Prof. H. Lamb (*Chairman*), Dr. A. T. Doodson (*Secretary*), Dr. G. R. Goldsbrough, Dr. H. Jeffreys, Prof. J. Proudman, Prof. G. I. Taylor, Prof. D'Arcy W. Thompson, Commander H. D. Warburg.

Annual Tables of Constants and Numerical Data, chemical, physical, and technological. —Sir E. Rutherford (*Chairman*), Prof. A. W. Porter (*Secretary*), Mr. Alfred Egerton. **£5** (Caird Fund grant, to be applied for from Council).

Calculation of Mathematical Tables.—Prof. J. W. Nicholson (*Chairman*), Dr. J. R. Airey (*Secretary*), Mr. T. W. Chaundy, Prof. L. N. G. Filon, Prof. E. W. Hobson, Mr. G. Kennedy, and Profs. Alfred Lodge, A. E. H. Love, H. M. Macdonald, G. B. Mathews. **£35** (for printing).

Investigation of the Upper Atmosphere.—Sir Napier Shaw (*Chairman*), Mr. C. J. P. Cave (*Secretary*), Prof. S. Chapman, Mr. J. S. Dines, Mr. L. H. G. Dines, Mr. W. H. Dines, Sir R. T. Glazebrook, Col. E. Gold, Dr. H. Jeffreys, Sir J. Larmor, Mr. R. G. K. Lempfert, Prof. F. A. Lindemann, Dr. W. Makower, Mr. J. Patterson, Sir J. E. Petavel, Sir A. Schuster, Dr. G. C. Simpson, Mr. F. J. W. Whipple, Prof. H. H. Turner.

To investigate local variations of the Earth's Gravitational Field.—Col. H. G. Lyons (*Chairman*), Capt. H. Shaw (*Secretary*), Mr. C. Vernon Boys, Dr. C. Chree, Col. Sir G. P. Lenox-Conyngham, Dr. J. W. Evans, Mr. E. Lancaster-Jones, the Director-General, Ordnance Survey; the Director, Geological Survey of Great Britain. **£50.**

SECTION B.—CHEMISTRY.

Colloid Chemistry and its Industrial Applications.—Prof. F. G. Donnan (*Chairman*), Dr. W. Clayton (*Secretary*), Mr. E. Hatschek, Prof. W. C. McC. Lewis, Prof. J. W. McBain. **£5.**

Absorption Spectra and Chemical Constitution of Organic Compounds.—Prof. I. M. Heilbron (*Chairman*), Prof. E. C. C. Baly (*Secretary*), Prof. A. W. Stewart. **£10.**

The Position of the Quantum Theory in its relations to Chemistry.—Prof. W. C. McC. Lewis (*Chairman*), Dr. J. Rice (*Secretary*), Prof. E. C. C. Baly, Prof. F. G. Donnan, Prof. A. Fowler, Dr. E. K. Rideal. **£10.**

The Chemistry of Vitamins.—Prof. F. G. Hopkins (*Chairman*), Prof. J. C. Drummond (*Secretary*), Prof. G. Barger, Prof. A. Harden, Principal J. C. Irvine, Prof. J. W. McBain, Prof. Lash Miller, Dr. S. Zilva.

SECTION C.—GEOLOGY.

The Old Red Sandstone Rocks of Kiltorcan, Ireland.—Mr. W. B. Wright (*Chairman*), Prof. T. Johnson (*Secretary*), Dr. W. A. Bell, Dr. J. W. Evans, Prof. W. H. Lang, Sir A. Smith Woodward. **£15.**

To excavate Critical Sections in the Palæozoic Rocks of England and Wales.—Prof. W. W. Watts (*Chairman*), Prof. W. G. Fearnsides (*Secretary*), Prof. W. S. Boulton, Mr. E. S. Cobbold, Dr. Gertrude Elles, Prof. E. J. Garwood, Mr. V. C. Illing, Prof. O. T. Jones, Dr. J. E. Marr, Dr. W. K. Spencer. **£20** (including £5 travelling fares).

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.—Prof. E. J. Garwood (*Chairman*), Prof. S. H. Reynolds (*Secretary*), Mr. G. Bingley, Messrs. C. V. Crook and A. S. Reid, Prof. W. W. Watts, and Messrs. R. Welch and W. Whitaker.

To investigate the Flora of Lower Carboniferous times as exemplified at a newly discovered locality at Gullane, Haddingtonshire.—Prof. W. W. Watts (*Chairman*), Prof. W. T. Gordon (*Secretary*), Dr. J. S. Flett, Prof. E. J. Garwood, Dr. J. Horne, and Dr. B. N. Peach.

To investigate the Stratigraphical Sequence and Palæontology of the Old Red Sandstone of the Bristol district.—Dr. H. Bolton (*Chairman*), Mr. F. S. Wallis (*Secretary*), Miss Edith Bolton, Prof. A. H. Cox, Mr. D. E. I. Innes, Prof. C. Lloyd Morgan, Prof. S. H. Reynolds, Mr. H. W. Turner. **£20.**

To investigate the Quaternary Peats of the British Isles.—Prof. P. F. Kendall (*Chairman*), Mr. L. H. Tonks (*Secretary*), Prof. P. G. H. Boswell, Miss Chandler, Prof. H. J. Fleure, Dr. E. Greenly, Prof. J. W. Gregory, Prof. G. Hickling, Mr. J. de W. Hinch, Mr. R. Lloyd Praeger, Mrs. Reid, Mr. T. Sheppard, Mr. J. W. Stather, Mr. A. W. Stelfox, Mr. C. B. Travis, Mr. A. E. Trueman, Mr. W. B. Wright. **£50.**

Comparison of the Rocks of Pre-Cambrian and presumably Pre-Cambrian Inliers of England and Wales and the Dublin Area with the Rocks of the Mona Complex of Anglesey, with a view to possible correlation.—Dr. Gertrude Elles (*Chairman*), Dr. Edward Greenly (*Secretary*), Mr. T. C. Nicholas, Prof. S. H. Reynolds, Dr. C. E. Tilley.

To investigate Critical Sections in the Tertiary Rocks of the London Area. To tabulate and preserve records of new excavations in that area.—Prof. W. T. Gordon (*Chairman*), Dr. S. W. Wooldridge (*Secretary*), Miss M. C. Crosfield, Prof. H. L. Hawkins, Prof. G. Hickling, Mr. W. Whitaker. **£15** (including £5 travelling fares).

To attempt to obtain agreement regarding the significance to be attached to Zonal Terms used in connection with the Lower Carboniferous.—Prof. P. F. Kendall (*Chairman*), Mr. R. G. Hudson (*Secretary*), Mr. J. W. Jackson, Mr. W. B. Wright. **£10**.

SECTION D.—ZOOLOGY.

To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.—Prof. E. S. Goodrich (*Chairman*), Prof. J. H. Ashworth (*Secretary*), Dr. G. P. Bidder, Prof. F. O. Bower, Dr. W. B. Hardy, Sir S. F. Harmer, Prof. S. J. Hickson, Sir E. Ray Lankester. **£100** from Caird Fund, subject to approval of Council.

Zoological Bibliography and Publication.—Prof. E. B. Poulton (*Chairman*), Dr. F. A. Bather (*Secretary*), Mr. E. Heron-Allen, Dr. W. T. Calman, Dr. P. Chalmers Mitchell, Mr. W. L. Sclater. **£1.**

Parthenogenesis.—Prof. A. Meek (*Chairman*), Mr. A. D. Peacock (*Secretary*), Mr. R. S. Bagnall, Dr. J. W. Heslop-Harrison. **£5.**

To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. A. Dendy (*Chairman and Secretary*), Prof. J. H. Ashworth, Prof. W. J. Dakin, Prof. S. J. Hickson, Sir E. Ray Lankester. **£25** (Caird Fund grant, to be applied for from Council).

To co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the Zoological Record.—Sir S. Harmer (*Chairman*), Dr. W. T. Calman (*Secretary*), Prof. A. Dendy, Prof. E. S. Goodrich, Prof. D. M. S. Watson. **£50** (Caird Fund grant, to be applied for from Council).

Pre-natal influence of Anti-sera on the Eye-lens of Rabbits.—Prof. W. J. Dakin (*Chairman*), Mr. J. T. Cunningham (*Secretary*), Prof. D. M. S. Watson. **£20.**

SECTION E.—GEOGRAPHY.

To consider the advisability of making a provisional Population Map of the British Isles, and to make recommendations as to the method of construction and reproduction.—Mr. H. O. Beckit (*Chairman*), Mr. F. Debenham (*Secretary*), Mr. J. Bartholomew, Prof. H. J. Fleure, Mr. R. H. Kinvig, Mr. A. G. Ogilvie, Mr. O. H. T. Rishbeth, Prof. P. M. Roxby. **£30.**

SECTIONS E, L.—GEOGRAPHY, EDUCATION.

To formulate suggestions for a syllabus for the teaching of Geography both to Matriculation Standard and in Advanced Courses; to report upon the present position of the geographical training of teachers, and to make recommendations thereon; and to report, as occasion arises, to Council through the Organising Committee of Section E, upon the practical working of Regulations issued by the Board of Education affecting the position of Geography in Training Colleges and Secondary Schools.—Prof. T. P. Nunn (*Chairman*), Mr. W. H. Barker (*Secretary*), Mr. L. Brooks, Prof. H. J. Fleure, Mr. O. J. R. Howarth, Sir H. J. Mackinder, Prof. J. L. Myres, and Prof. J. F. Unstead (*from Section E*); Mr. Adlam, Mr. D. Berridge, Mr. C. E. Browne, Sir R. Gregory, Mr. E. Sharwood Smith, Mr. E. R. Thomas, Miss O. Wright (*from Section L*). **£5.**

SECTION G.—ENGINEERING.

To report on certain of the more complex Stress Distributions in Engineering Materials. —Prof. E. G. Coker (*Chairman*), Prof. L. N. G. Filon and Prof. A. Robertson (*Secretaries*), Prof. T. B. Abell, Prof. A. Barr, Mr. Charles Brown, Dr. Gilbert Cook, Prof. W. E. Dalby, Sir J. A. Ewing, Sir H. Fowler, Mr. A. R. Fulton, Dr. A. A. Griffith, Mr. J. J. Guest, Dr. B. P. Haigh, Profs. Sir J. B. Henderson, C. E. Inglis, F. C. Lea, A. E. H. Love, and W. Mason, Sir J. E. Petavel, Dr. F. Rogers, Dr. W. A. Scoble, Mr. R. V. Southwell, Dr. T. E. Stanton, Mr. C. E. Stromeyer, Mr. G. I. Taylor, Mr. A. T. Wall, Mr. J. S. Wilson. **£10.**

SECTION H.—ANTHROPOLOGY.

To report on the Distribution of Bronze Age Implements.—Prof. J. L. Myres (*Chairman*), Mr. H. Peake (*Secretary*), Mr. Leslie Armstrong, Mr. H. Balfour, Prof. T. H. Bryce, Mr. L. H. D. Buxton, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Dr. Cyril Fox, Mr. G. A. Garfitt, Prof. Sir W. Ridgeway. **£100** (Caird Fund grant, to be applied for from Council).

To conduct Archæological Investigations in Malta.—Prof. J. L. Myres (*Chairman*), Sir A. Keith (*Secretary*), Dr. T. Ashby, Mr. H. Balfour.

To conduct Explorations with the object of ascertaining the Age of Stone Circles.—Sir C. H. Read (*Chairman*), Mr. H. Balfour (*Secretary*), Dr. G. A. Auden, Prof. Sir W. Ridgeway, Dr. J. G. Garson, Sir Arthur Evans, Sir W. Boyd Dawkins, Prof. J. L. Myres, Mr. H. J. E. Peake.

To excavate Early Sites in Macedonia.—Prof. Sir W. Ridgeway (*Chairman*), Mr. S. Casson (*Secretary*), Prof. R. C. Bosanquet, Dr. W. L. H. Duckworth, Prof. J. L. Myres, Mr. M. Thompson.

To report on the Classification and Distribution of Rude Stone Monuments.—Mr. G. A. Garfitt (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mr. O. G. S. Crawford, Miss R. M. Fleming, Prof. H. J. Fleure, Dr. C. Fox, Mr. G. Marshall, Prof. J. L. Myres, Mr. H. J. E. Peake. **£5.**

The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.—Mr. E. Torday (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Dr. G. A. Auden, Dr. H. A. Auden, Mr. E. Heawood, Prof. J. L. Myres.

To report on the probable sources of the supply of Copper used by the Sumerians.—Mr. H. J. E. Peake (*Chairman*), Mr. G. A. Garfitt (*Secretary*), Mr. H. Balfour, Mr. L. H. Dudley Buxton, Prof. C. H. Desch, Sir Flinders Petrie.

To conduct Archæological and Ethnological Researches in Crete.—Dr. D. G. Hogarth (*Chairman*), Prof. J. L. Myres (*Secretary*), Prof. R. C. Bosanquet, Dr. W. L. H. Duckworth, Sir A. Evans, Prof. Sir W. Ridgeway, Dr. F. C. Shrubsall.

To report on the present state of knowledge of the relation of early Palæolithic Implements to Glacial Deposits.—Mr. H. J. E. Peake (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mr. H. Balfour, Prof. P. G. H. Boswell, Mr. M. Burkitt, Prof. P. F. Kendall, Mr. G. Lamplugh, Prof. J. E. Marr. **£30.**

To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.—Sir W. Boyd Dawkins (*Chairman*), Mr. Willoughby Gardner (*Secretary*), Mr. H. Balfour, Mr. A. Bulleid, Mr. F. S. Palmer, Mr. H. J. E. Peake.

To co-operate with a Committee of the Royal Anthropological Institute in the exploration of Caves in the Derbyshire district.—Sir W. Boyd Dawkins (*Chairman*), Mr. G. A. Garfitt (*Secretary*), Mr. Leslie Armstrong, Mr. M. Burkitt, Mr. E. N. Fallaize, Dr. R. V. Favell, Mr. Wilfrid Jackson, Dr. R. R. Marett, Mr. L. S. Palmer, Mr. H. J. E. Peake.

To investigate processes of Growth in Children, with a view to discovering Differences due to Race and Sex, and further to study Racial Differences in Women.—Sir A. Keith (*Chairman*), Prof. H. J. Fleure (*Secretary*), Mr. L. H. Dudley Buxton, Dr. A. Low, Prof. F. G. Parsons, Dr. F. C. Shrubsall. **£20.** (A proportion not exceeding two-thirds of this grant may be expended on railway fares incurred in course of the investigation.)

To conduct Excavations and prepare a Survey of the Coldrum Megalithic Monument.—Sir A. Keith (*Chairman*), Prof. H. J. Fleure (*Secretary*), Mr. H. J. E. Peake. **£20.**

To report on proposals for an Anthropological and Archæological Bibliography, with power to co-operate with other bodies.—Dr. A. C. Haddon (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Dr. T. Ashby, Mr. W. H. Barker, Mr. O G. S. Crawford, Prof. H. J. Fleure, Prof. J. L. Myres, Mr. H. J. E. Peake, Dr. D. Randall-MacIver, Mr. T. Sheppard.

To report on the progress of Anthropological Teaching in the present century.—Dr. A. C. Haddon (*Chairman*), Prof. J. L. Myres (*Secretary*), Prof. H. J. Fleure, Dr. R. R. Marett, Prof. C. G. Seligman. **£5.**

To investigate certain Physical Characters and the Family Histories of Triplet Children.—Dr. F. C. Shrubsall (*Chairman*), Mr. R. A. Fisher (*Secretary*), Miss R. M. Fleming, Dr. A. Low. **£25.**

To report on the possibility of Physiological Tests of Races, such as the Blood Agglutination.—Dr. F. C. Shrubsall (*Chairman*), Mr. L. H. Dudley Buxton (*Secretary*), Dr. Davidson Black, Dr. H. H. Dale, Dr. A. C. Haddon, Prof. G. H. F. Nuttall.

To conduct Explorations on early Neolithic Sites in Holderness.—Mr. H. J. E. Peake (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Mr. M. Burkitt, Dr. R. V. Favell, Mr. G. A. Garfitt, Mr. Wilfrid Jackson, Mr. L. S. Palmer.

To conduct Anthropometric Investigations among the Indians of the Canadian Rockies.—Dr. A. C. Haddon (*Chairman*), Mr. H. Balfour (*Secretary*), Dr. E. Sapir. **£100.**

SECTION I.—PHYSIOLOGY.

Muscular Stiffness in relation to Respiration.—Prof. A. V. Hill (*Chairman*), Dr. Ff. Roberts (*Secretary*), Mr. J. Barcroft.

The Cost of Cycling with varied rate and work.—Prof. J. S. Macdonald (*Chairman*), Dr. F. A. Duffield (*Secretary*). **£30.**

The Investigation of the Medullary Centres.—Prof. C. Lovatt Evans (*Chairman*), Mr. J. M. Duncan Scott (*Secretary*), Dr. H. H. Dale. **£20.**

SECTION J.—PSYCHOLOGY.

The Place of Psychology in the Medical Curriculum.—Prof. G. Robertson (*Chairman*), Dr. J. Drever (*Secretary*), Dr. W. Brown, Dr. R. G. Gordon, Dr. C. S. Myers, Prof. T. H. Pear, Dr. F. C. Shrubsall.

Vocational Tests.—Dr. C. S. Myers (*Chairman*), Dr. G. H. Miles (*Secretary*), Mr. C. Burt, Prof. T. H. Pear, Mr. F. Watts, Dr. Ll. Wynn-Jones.

The Character of a first-year University Course in Experimental Psychology.—Dr. J. Drever (*Chairman*), Dr. May Collins (*Secretary*), Mr. F. C. Bartlett, Mr. R. J. Bartlett, Prof. E. A. Bott, Dr. C. Burt, Dr. Shepherd Dawson, Mr. A. E. Heath, Dr. Ll. Wynn-Jones, Prof. T. H. Pear.

The uniformity of Terminology and Standards in the Diagnosis of Mental Deficiency.—Dr. C. Burt (*Chairman*), Miss Evelyn Fox (*Secretary*), Miss L. G. Fildes, Dr. Kennedy Fraser, Dr. F. C. Shrubsall.

SECTION K.—BOTANY.

The Physiology and Life-history of Marine Algæ at Port Erin.—Prof. J. McLean Thompson (*Chairman*), Dr. M. Knight (*Secretary*), Prof. F. E. Weiss. **£25.**

Index Kewensis.—Sir D. Prain (*Chairman*), Dr. A. W. Hill (*Secretary*), Prof. J. B. Farmer, Dr. A. B. Rendle, Prof. W. Wright Smith. **£100.**

Botanical Survey of Sherwood Forest.—Prof. R. H. Yapp (*Chairman*), Dr. H. S. Holden (*Secretary*), Mr. A. G. Tansley. (With power to apply unexpended balance of last year's grant.)

SECTION L.—EDUCATIONAL SCIENCE.

To inquire into the Practicability of an International Auxiliary Language.—Dr. H. Forster Morley (*Chairman*), Dr. E. H. Tripp (*Secretary*), Mr. E. Bullough, Prof. J. J. Findlay, Sir Richard Gregory, Mr. W. B. Hardy, Dr. C. W. Kimmins, Sir E. Cooper Perry, Mr. Nowell Smith, Mr. A. E. Twentyman. **£3.**

To consider the educational training of boys and girls in Secondary Schools for overseas life.—Rev. H. B. Gray (*Chairman*), Mr. C. E. Browne (*Secretary*), Dr. J. Vargas Eyre, Sir R. A. Gregory, Sir J. Russell. **£20.**

CORRESPONDING SOCIETIES.

Corresponding Societies Committee.—The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), the General Secretaries, the General Treasurer, Dr. F. A. Bather, Mr. O. G. S. Crawford, Prof. P. F. Kendall, Mr. Mark L. Sykes, Dr. C. Tierney, Prof. W. W. Watts, Mr. W. Whitaker; with authority to co-opt representatives of Scientific Societies in the locality of the Annual Meeting. **£40** for preparation of bibliography and report.

THE CAIRD FUND.

An unconditional gift of £10,000 for research was made to the Association at the Dundee Meeting, 1912, by Mr. (afterwards Sir) J. K. Caird, LL.D., of Dundee.

The Council, in its report to the General Committee at the Birmingham Meeting, made certain recommendations as to the administration of this Fund. These recommendations were adopted, with the Report, by the General Committee at its meeting on September 10, 1913.

The allocations made from the Fund by the Council to September 1922 will be found stated in the *Report* for 1922, p. xxxi. Subsequent grants from the fund are incorporated in the lists of Research Committees.

In 1921-23, the Council authorised expenditure from accumulated income of the fund upon grants to Research Committees approved by the General Committee by way of supplementing sums available from the general funds of the Association, and in addition to grants ordinarily made by, or applied for from, the Council.

Sir J. K. Caird, on September 10, 1913, made a further gift of £1,000 to the Association, to be devoted to the study of Radio-activity. In 1920 the Council decided to devote the principal and interest of this gift at the rate of £250 per annum for five years to purposes of the research intended. The grants for the year ending March 24, 1922 and 1923, were made to Sir E. Rutherford, F.R.S. The grant for the year ending March 24, 1924, was made to Prof. F. Soddy, F.R.S. The grant for the year ending March 24, 1925, was divided between Messrs. C. T. R. Wilson (£100), J. Chadwick (£75), and A. S. Russell (£75).

RESOLUTIONS & RECOMMENDATIONS.

The following Resolutions and Recommendations were received and approved by the General Committee at Toronto, and, with the exception of the first, were referred to the Council for consideration, and, if desirable, for action.

From Section B.

That the sectional meetings on the Western Excursion be regarded as a part of the official programme of the Association.

From Sections E, F, H and L.[1]

That the Council be requested to submit to His Majesty's Government and to the Universities Bureau that in any scheme for applying funds from the Boxer Indemnity to the provision of further facilities for higher education and research in China, account should be taken of the urgent need for the foundation of an institute in China for the purpose of education and research in geographical, economic and social conditions.

Resolutions on International Service of Biological Abstracts.

SECTION C approves in principle the proposals to establish an international service of biological abstracts as formulated by the Union of American Biological Societies, on the understanding that the biological (including systematic) side of palæontology will be included, as it already is in the Zoological Record, with which all possible continuity should be maintained; further, it suggests to the Council that eventual details of arrangements and indexing should be reported on by the Association's Committee on Zoological Bibliography and Publication.

SECTION D heartily approves in principle the proposal of the Union of American Biological Societies for the institution of an international comprehensive series of biological abstracts, and recommends the General Committee to authorise the Council to take the necessary steps to bring about the collaboration of British workers.

The Committee of Section D hopes that, in any such scheme, means may be found to preserve all possible continuity with the existing Zoological Record.

SECTION H resolves: To ask the Council to support the proposal put forward by the National Research Council, U.S.A., for the institution of an international abstracting service for all biological sciences.

SECTION I.—The Committee of the Section, which is in close touch with the Physiological Societies of both Great Britain and America, while it desired a sympathetic approach to our American colleagues in this matter, hoped the Physiological Section of the new Biological Abstracts would be arranged in co-operation with those responsible for the publication of physiological abstracts in England. The Committee desired that Prof. H. C. Bazett of Philadelphia be appointed as a member of the Publication Committee of the proposed Abstracts, to make possible this co-operation, this appointment being made in response to the request of those speaking on behalf of biological abstracts.

SECTION J.—The Section of Psychology cordially welcomes efforts to arrange international co-operation in making and publishing abstracts of work bearing on psychology. Some progress has already been made by psychologists in this direction. The Section believes that there should be a considerable degree of national decentralisation.

The Section further sympathises with plans for co-operation among the different biological sciences. It should be noted, however, that the relations of psychology are not only with the biological sciences, and psychologists would especially welcome methods by which they could obtain abstracts of all papers bearing on psychology without subscribing for abstracts unrelated to it.

SECTION K resolved: That the Committee of Section K heartily supports the proposal for the establishment of an International Journal for the Abstracting of Biological Publications, and instructs its representative (Dr. Rendle) to express this view to the Committee which is considering this matter in Toronto.

SECTION M favours the general plan for a comprehensive Journal of Biological Abstracts as outlined in *Science*, of September 28, 1923, and presented to the Association by representatives of the American Union of Biological Societies, and accepts the invitation to appoint representatives on the Joint Publication Committee of the Union and the National Research Council of the United States.

[1] The terms of the resolutions in this group did not materially differ.

THE PRESIDENTIAL ADDRESS.

PREVENTION OF DISEASE.

BY

MAJOR-GENERAL SIR DAVID BRUCE, K.C.B., F.R.S., A.M.S.,

PRESIDENT OF THE ASSOCIATION.

My first duty is to thank the General Committee of the British Association for the great honour they have done me by electing me to the post of President. I must confess I wondered at first why I had been chosen, but soon came to the conclusion that it was an honour done through me to all Army Medical Officers for the magnificent work done by them during the Great War, in the prevention of disease and alleviation of pain and suffering.

In the next place, I may be permitted to remind you that this is the fourth time the British Association for the Advancement of Science has met in Canada—first in 1884 in Montreal, in this city in 1897, and in Winnipeg in 1909.

The addresses given on these occasions dealt with the advancement of knowledge in Archæology and Physics.

It is now my privilege, as a member of the medical profession, to address you on the advances made during the same period in our knowledge of disease and our means of coping with and preventing it.

An address on the prevention of disease at first sight does not promise to be a very pleasant subject, but, after all, it is a humane subject, and also a most important subject, as few things can conduce more to human happiness and human efficiency than the advancement of knowledge in the prevention of disease.

Think for a moment of the enormous loss of power in a community through sickness. Some little time ago the English Minister of Health, when emphasising the importance of preventive work, said that upwards of 20,000,000 weeks of work were lost every year through sickness, among insured workers in England. In other words, the equivalent of the work of 375,000 people for the whole year had been lost to the State. When to that is added the corresponding figure for the non-insured population you get some idea of the importance of preventive work.

Another way of estimating the value of prevention is in terms of dollars, or pounds, shillings, and pence, and it has lately been calculated that the direct loss in England and Wales from sickness and disability amounts to at least 150,000,000*l*. a year. In the United States, with a much larger population, the loss is put down at 600,000,000*l*.

Another reason why this is an important subject is that medicine in the future must change its strategy, and instead of awaiting attack must assume the offensive. Instead of remaining quietly in the dressing stations and field hospitals waiting for the wounded to pour in, the scientific services must be well forward in the enemy's country, destroying lines of communication, aerodromes, munition factories, and poison-gas centres, so that the main body of the army may march forward in safety.

It must no longer be said that the man was so sick he had to send for the doctor.

The medical practitioner of the future must frequently examine the man while he is apparently well, in order to detect any incipient departure from the normal, and to teach and urge modes of living conformable to the laws of personal health, and the Public Health Authorities must see to it that the man's environment is in accordance with scientific teaching.

It may be a long time before the change is widely accepted, but already enormous advances have been effected, and it only depends on the intelligence and education of the populations how rapid the future progress will be.

Public opinion must be educated to recognise that most diseases are preventable and to say with King Edward VII., 'If preventable, why not prevented?'

To our forefathers disease appeared as the work of evil spirits or magicians, or as a visitation of Providence to punish the individual or the community for their sins.

It is not my purpose to give a detailed account of the first strivings after a better knowledge of the causes of disease, but it may be said the new era began some few hundred years ago, when it was recognised that certain diseases were contagious.

For a long time it was held that this contagion or infection was due to some chemical substance passing from the sick to the healthy, and acting like a ferment; and then, about the middle of last century, the idea gradually grew that microscopic creatures might be the cause.

About this time it had been discovered that the fermentation of grape

juice was caused by a living cell and that certain contagious skin-diseases were associated with living fungi.

Things were in this position when there appeared on the scene a man whose genius was destined to change the whole aspect of medicine; a man destined to take medicine out of the region of vague speculation and empiricism, and set its feet firmly on new ground as an experimental biological science. I mean the Frenchman, Louis Pasteur. It is from him we date the beginning of the intelligent, purposive prevention of disease. It was he who established the germ theory, and later pointed the way to the immunisation of man and animals, which has since proved so fruitful in measures for the prevention or stamping out of infectious diseases.

I need not discuss his life and work further. His name is a household word among all educated and civilised peoples. Every great city should put up a statue to him, to remind the rising generations of one of the greatest benefactors of the human race.

What the change in medicine has been, is put into eloquent language by Sir Clifford Allbutt: 'At this moment it is revealed that medicine has come to a new birth. What is, then, this new birth, this revolution in medicine? It is nothing less than its enlargement from an art of observation and empiricism to an applied science founded upon research; from a craft of tradition and sagacity to an applied science of analysis and law; from a descriptive code of surface phenomena to the discovery of deeper affinities; from a set of rules and axioms of quality to measurements of quantity.'

With one notable exception, the medical profession were not quick to see that Pasteur's discoveries of the nature of fermentation and putrefaction had a message for them. This exception was Joseph Lister, who had been for some years endeavouring to comprehend the cause of sepsis and suppuration, which commonly followed every surgical operation and most serious injuries involving a breach of the skin.

When, in 1865, Lister read Pasteur's communication upon fermentation, the bearing of the discovery on the problems which had so earnestly engaged his attention was apparent to him. He inferred that suppuration and hospital gangrene, the causes of which had so far baffled his imagination, were due to microbes introduced from the outside world, from the air, and by instruments and hands of the operator. Remember, this was years before the microbial causation of any disease was established.

To test the correctness of his inference, Lister proceeded to submit all instruments, ligatures, materials for dressings, and everything that was

to come directly or indirectly into contact with the wound, the hands of the operator, and the skin of the patient, to treatment with chemical disinfectants.

The satisfactory results which followed this practice astonished even Lister, and he spent the rest of his active life in improving and simplifying technical methods of preventing the ingress of microbes to wounds, and in convincing his professional brethren of the truth of the conclusions based on this work of Pasteur.

INFECTIOUS DISEASES.—(A) BACTERIAL.

As soon as it was recognised that infectious diseases are caused by living germs a wave of enthusiasm swept through the medical world, and it was not long before the causation of many of the most important of them was discovered. I need not give a full list of these, but at or round about the time of the first meeting of the British Association in Canada the micro-organisms of tuberculosis, typhoid fever, Malta fever, cholera, malaria, diphtheria, tetanus, and others had been discovered and described.

But it must not be assumed from what has been said that all the most important diseases are caused by living germs. Many of the ills that afflict mankind are due to quite other causes—alcoholism, for example, or the deficiency diseases, due to the absence or deficiency in our diet of some substance essential to proper growth and development. Rickets, one of the greatest scourges of industrial communities, is mainly a deficiency disease. It is reported that as many as 50 per cent. of the children in the slums of some of our big cities suffer from the effects of this disease.

Then again, there is the whole series of diseases or conditions due to defective or excessive action of our own internal glands.

Added to these, and perhaps the greatest scourge of all, there is the immense amount of chronic ill-health and actual disease caused or promoted by the unhealthy conditions found in our large cities, due to bad housing and overcrowding—the so-called diseases of environment.

Malta Fever.

But to return to the infectious diseases. After the living germs or parasites causing them had been isolated the process of prevention was soon begun. The methods employed were varied, and I may illustrate one of the simplest by relating briefly the history of the prevention of Malta fever, with which I was myself, to some extent, associated.

Malta fever is really a widespread disease, although it is called by a local name. It is found all round the Mediterranean, throughout Africa as

far south as the Cape Province, in India and China, and even in some parts of America. It was very prevalent in Malta in the old days, and rendered the island one of the most unhealthy of all our foreign military stations. When I arrived in Malta, in 1884, I found that every year, on an average, some 650 soldiers and sailors fell victims to it, and, as each man remained on an average 120 days in hospital, this gave the huge total of about 80,000 days of illness per annum from this fever alone.

The British had held Malta since the beginning of last century, and although much attention had been given to the fever and its symptoms had been fully described, no advance was made towards its prevention until 1887, when the living germ, the *Micrococcus melitensis*, causing it was discovered.

At this time a good deal of work was expended in studying the natural history of the fever and the micrococcus, but all to no purpose. Nothing was discovered to give a clue to any method of prevention.

At the Naval Hospital especially everything in the way of prevention was done that could be thought of: the water supply and drainage were thoroughly tested, the walls were scraped and every corner rounded off where dust might lie, immaculate cleanliness reigned; but all these precautions proved useless. Almost every sailor who came into the hospital even for the most trivial complaint took Malta fever, and after a long illness had to be invalided to England.

Things remained in this very unsatisfactory state for seventeen years, until 1904, when the Admiralty and War Office, alarmed at the amount of sickness and invaliding in the Malta garrison, asked the Royal Society of London to undertake the investigation of the fever. This was agreed to, and a Commission was accordingly sent out in the same year and remained at work until 1906.

During the first year every likely line of approach was tried. A careful study was made as to how the micrococcus entered the body, how it left the body, its behaviour outside the body, its pathogenic action on various animals; but still no indication of a method of prevention showed itself.

Next year, however, in 1905, the problem of prevention was solved, and that by the merest of accidents.

In the previous year experiments had been made with the object of finding out if the goat, among other animals, was susceptible to the disease. The goats in Malta, which supply all the milk, are very much in evidence, as they are driven about in small herds and milked as required at the doors of customers. Several goats had been injected with cultures of the

micrococcus, but, as they showed no rise of temperature or any signs whatever of ill-health, they were put aside as being immune or refractory to the disease and nothing more was thought about them.

In the spring of 1905, about six months after these experiments had been made, Dr. Zammit, a Maltese member of the Commission, who had kept one of two of these goats, happened for some reason or other to examine their blood, and found that it clumped or agglutinated the micrococcus. This was strange, and seemed to show that, although the micrococcus had not caused fever or any signs of illness in the goats, it must have lived and multiplied in the tissues of these animals in order to have brought about this change in the blood.

This observation led to the re-examination of the immunity of the goat, when the extraordinary discovery was made that about 50 per cent. of the goats in the island were affected by this disease, and that 10 per cent. of them were actually excreting the micrococcus of Malta fever in their milk.

Monkeys fed on milk from an affected goat, even for one day, almost invariably took the disease.

Thus the weak link in the chain of causation had been found. The military authorities struck Maltese milk out of the dietary, and replaced it by an imported variety, and from that day to this there has scarcely been a case of Malta fever in the garrison. Malta, from being the most unhealthy of foreign stations, became a health resort, and was in fact used as a sanatorium during the late war. The disease had been blotted out at a single blow.

This, then, is one way of preventing an infectious disease ; that is to say, by the discovery of the living germ, the study of its natural history, and so to a means of stopping it reaching its victim, man. This is the best way of prevention : shutting the stable door before the horse is stolen.

Typhoid Fever.

But there are other ways of preventing bacterial diseases. Let us take, for example, a method widely used in the prevention of typhoid fever.

The fundamental and sound way of attacking this disease is by ordinary hygienic measures, especially a good water supply and good drainage. It is therefore one of the first duties of those in power to see that their people have, in addition to houses with plenty of light and air, a good water supply and a good drainage system, and money cannot be spent to better advantage than in the attainment of these three essentials to health.

When typhoid fever is rife in a community it means that there is

either a contaminated water supply or a faulty drainage system, and the municipal authorities ought to be called to account. In England, owing to improved sanitation, cases of typhoid fever are fifteen times less than they were fifty years ago.

But it is not always possible to ensure good hygienic surroundings—for example, among troops on active service. It is therefore legitimate under certain conditions, and especially in time of war, to practise a less sound, a less fundamental, method of prevention, and this second method is known as inoculation or vaccination.

In order to understand how this acts, let us consider, for a moment, what takes place in a man's body when he is attacked by the typhoid bacillus. Everybody knows that the bacillus gives rise to poisons or toxins which cause the fever and other symptoms. But the cells and tissues of the man are not passive under the attack. They at once begin to fight against the infection, by forming substances in the blood to neutralise these toxins, hence called antitoxins or antibodies, and their function is finally to destroy the invading germs. If the man recovers he is immune from a further attack by the presence of these antibodies in his blood. He has become immune by passing through an attack of the disease.

This is the foundation of the second way of preventing infectious diseases. Speaking broadly, it means that you subject a man to a mild attack of the fever in order that his blood and tissues will respond to the stimulus by producing antibodies.

This method takes its origin and name from that of vaccination against smallpox. Jenner solved that problem by the accidental discovery of vaccinia, a form of smallpox attenuated or weakened by passage through another species of animal. This weakening of the virulence of a micro-organism by passage through another kind of animal is by no means uncommon in nature.

Pasteur, following on these lines, conceived the idea of weakening or attenuating the virulence of the living bacilli by artificial means, so as to give rise to a mild attack of the disease, and in this way to render animals immune. This he did with marked success in anthrax and chicken cholera.

The next forward step in this method of preventing disease was made by Haffkine, a pupil of Pasteur, who about the year 1894 produced a vaccine against cholera, and a few years later another, against plague.

In the course of this work it was discovered that it was not necessary to use living cultures of the bacilli, but that vaccines made up of dead

bacilli had much the same effect. This substitution of the dead bacilli for the living was a great advance in the method, being much simpler and much safer.

The next disease to be attacked by this method was typhoid fever. This was initiated by Sir Almroth Wright at the British Army Medical School, and carried out with that scientist's characteristic ability and energy. The method was mainly directed in the first place to lessen the mortality from this disease among our soldiers serving in India.

After several years' experience, the mode of inoculation which was finally settled on was to give two injections of dead typhoid bacilli, one of 500 millions, and a second, at an interval of ten days, of a thousand millions.

Now let us see what effect anti-typhoid inoculation has had on the prevention of typhoid fever among our soldiers in the field.

In the South African War, at the beginning of the century, before the method had been developed, in an army the average strength of which was only 208,000 there were 58,000 cases of typhoid fever and 8,000 deaths.

In the Great War, on the Western Front, with an average British strength of one and a quarter millions, there were only 7,500 cases and 266 deaths. In other words, there were fewer cases of the disease in this war than there were deaths in the South African.

It is also interesting to learn from French sources that at the beginning of the war the French soldiers were not inoculated, whereas the British were. The result for the first sixteen months was striking. During this time the French had some 96,000 cases, with nearly 12,000 deaths. The British had only 2,689 cases and 170 deaths. Afterwards the French soldiers were very thoroughly vaccinated, with the result that their immunity eventually became as striking as our own.

What the number of cases and death-rate from typhoid fever might have been in the huge armies fighting on the different fronts had it not been for this preventive inoculation it is impossible to say, but undoubtedly the suffering and loss of life would have been enormous.

I may therefore conclude this account of anti-typhoid inoculation by saying that it certainly constituted one of the greatest triumphs in the prevention of disease during the recent war.

Tetanus and Diphtheria.

I shall now pass on to consider a third method of preventing bacterial diseases which has also been evolved during the time under review; that is, by the injection of specially prepared blood sera. These are known

as antitoxic sera, and the most familiar examples are anti-tetanic and anti-diphtheritic.

We have seen how the injection of living or dead bacilli or their toxins into animals gives rise to the production of antibodies or antitoxins. The blood serum of such animals in virtue of the antibodies contained in it can be used to combat disease.

Let us take in the first place the case of tetanus, until recently considered to be one of the most fatal of maladies, at least 85 per cent. of the cases succumbing.

As you are aware, anti-tetanic serum is prepared by injecting horses with large quantities of tetanus toxin. When the blood is as full as possible of antibodies it is drawn off and the serum allowed to separate out.

The idea lying behind this third method of preventing disease is to pour in these ready-made antitoxins in order to assist the body in its first struggle with the invading disease, and give it, as it were, a breathing space to prepare its own defences.

Naturally the immunity produced by these antitoxic sera is of a passive nature, and of short duration, as compared with that produced by the disease itself, or even by the milder form brought about by vaccination or inoculation.

Anti-typhoid inoculation will protect a soldier for, let us say, two years; anti-tetanic serum will protect for only a week or ten days. It is therefore impossible to inoculate a whole army against tetanus. It is necessary to wait until there is a danger of the disease occurring.

To illustrate this I shall describe briefly the history of the prevention of tetanus during the Great War.

When the British Expeditionary Force went over to France, in August 1914, only a small quantity of anti-tetanic serum was taken, and that for the purpose of treatment rather than prevention. But shortly after the outbreak of hostilities the number of cases of tetanus among the wounded became so alarming that no time was lost in grappling with the danger. Large quantities of serum were hurried to the front, and some two months after the beginning of the war it was possible to make an order that every wounded man should receive an injection of anti-tetanic serum as soon after he was wounded as possible. Later on, after further experience had been gained, the single injection was increased to four, given at intervals of a week. This helped the wounded man over the dangerous time and the results were very successful.

In August and September 1914, before the prophylactic injection was

given, roughly speaking nine or ten out of every thousand wounded were attacked by tetanus and some 85 per cent. of these died.

After the anti-tetanic injections had been introduced the incidence fell to little more than one per thousand, and the mortality to less than half.

To put the matter broadly: during the war there were 2,500 cases of tetanus in the British Army, with 550 deaths. If there had been no prophylactic injection of anti-tetanic serum there would probably have been 25,000 cases with 20,000 deaths—a very striking example of the recent development in the prevention of disease.

Another very important and widespread disease, somewhat resembling tetanus, is diphtheria, and there is no better example of the advance of science in methods of cure and prevention than is found in this disease.

Thanks to the work of Klebs and Löffler in the early 'eighties and, some years later, to the brilliant researches of Roux and Yersin, the causation and natural history of this disease were very thoroughly elucidated.

Anti-diphtheritic serum is prepared much in the same way as the anti-tetanic. By the repeated injections of gradually increasing doses of the bacilli or their toxins, a serum is produced which has a marked curative effect in cases of diphtheria.

It is stated that the introduction of anti-diphtheritic serum in 1894 has reduced the death-rate from 40 to 10 per cent., and if used on the first day of the disease to almost *nil*.

The serum is essentially a curative agent and is useful only to a limited extent in prevention.

But lately essentially preventive measures in diphtheria have come into vogue. The procedure employed is to bring about an active immunisation by a mixture of toxin and antitoxin in individuals who have been shown to be susceptible to the disease by what is known as the Schick test.

In the United States a campaign on these lines has been begun against this disease which promises brilliant results. It is confidently stated that by their new measures there is a possibility of robbing diphtheria of all its powers to kill or injure.

The mode of prevention of these diseases—Malta fever, typhoid fever, and tetanus—illustrates the three principal methods of preventing bacterial diseases: in Malta fever, by getting down to bed-rock and stopping the disease at its source; in typhoid fever, by giving, as it were, a mild attack of the disease, by vaccination or inoculation, so as to bring about a greater

power of resistance; in tetanus, by pouring in antitoxins, already prepared in the serum of another animal, in order that they may neutralise the toxins of the invading bacilli as soon as they are formed.

Tuberculosis.

There are other important bacterial diseases, however, which cannot be attacked so simply.. For example, there is tuberculosis, a disease distributed over the whole world and one of the greatest scourges of civilised communities. It is a disease which has been known from time immemorial, but it is only within our own time that the bacterial cause has been recognised. I can well remember a day in 1882 when I met a fellow-student who had just returned to Edinburgh from Germany. He told me that it had been recently discovered that the disease was really caused by a living germ, the tubercle bacillus. It was difficult at first to believe such a revolutionary idea, but such was the interest and excitement raised that many workers at once took up the study of the subject and in a short time the truth of Koch's great discovery was fully proved. This was a magnificent example of research work, most admirably, carefully, and completely carried out, and placed Koch at once in the front rank of scientific workers.

Before Koch's discovery a good deal had been done in the way of prevention. Before all things, this disease is a disease of environment. Its birthplace and home is the sunless, ill-ventilated, overcrowded room. The late Professor Edmund Parkes, Professor of Hygiene at the Army Medical School, reduced to a great extent the incidence of tuberculosis in the British Army by procuring for the soldier more floor-space and more air-space in his barracks. It is related of General von Moltke that when he heard of the death of Parkes he said that every regiment in Europe should parade on the day of his funeral and present arms in honour of one of the greatest friends the soldier ever had.

The prevention of tuberculosis is thus seen to depend fundamentally on the provision of a better environment and the education of the people in physiological living.

To attain this in the older civilisations will be a hard task, entailing enormous expenditure of money and energy. In the Report of the Royal Commission on the Housing of the Industrial Population of Scotland in 1917 is described the unsatisfactory sites of houses and villages, insufficient supplies of water, unsatisfactory provision for drainage, the gross overcrowding in the congested industrial towns, occupation of one-room houses

by large families, groups of lightless and unventilated houses in the older burghs, clotted masses of slums in the great cities—a terrible picture, the heritage of the age of ignorance, internal strife, and walled towns.

The people of new countries should see to it, and doubtless will see to it, that these old evils are not perpetuated.

As Sir Robert Philip, Professor of Tuberculosis in the University of Edinburgh, has eloquently said: 'Were it possible to begin afresh the scheme of civilised life, were it possible to undertake anew the creation of cities and the homes of our people, were it possible to place within the re-created dwellings an understanding race, de-tuberculisation might be quickly attained. What a magnificent opportunity for the builders of the new cities, the moulders of fresh civilisations, with the grand purpose of "No tuberculosis." The architect, the sanitarian, and the citizen would agree in insisting that physiological laws should be paramount, that there should be effective obedience to the larger demands of hygiene in the home, the school, the workshop, the meeting-place and the cow-shed.

'Mankind was born into air and sunlight: these are his natural heritage. They are more—they are the irreducible conditions of life.'

In regard to the tubercle bacillus it is so widespread, so ubiquitous in civilised communities, passing from one infected host to infect another, that it would seem impossible under existing conditions to prevent its spread. At present it is taught, and on what seems good evidence, that the majority of the population of our crowded cities has at one time or another been attacked by this disease. But in every hundred men who die in England, only about ten die of tuberculosis, which shows that a large percentage of the population successfully resists the tubercle bacillus.

When this occurs it means that the person attacked possessed powers of resistance which enabled him either to destroy the invading bacilli or to deal with them so as to render them harmless.

A point of importance in this connection is that it has recently been demonstrated that the disease is usually acquired in childhood. The fact is of capital significance, for if the disease is recognised sufficiently early, and the child is placed under good hygienic conditions, there is a very good chance of effective resistance and immunity against a second attack being set up.

The present evidence goes to show that the presence of latent tubercle prevents a second invasion. If further outbreaks take place, they would seem to be due to a flaring up of the old latent tubercle rather than to a fresh infection.

Metchnikoff studied the question in a remote part of Siberia where the tubercle bacillus was unknown. He states that very many of the young men and women who migrated from this clean country into the big cities died of acute and rapid tuberculosis, on account of not having been exposed to infection in their childhood.

The experience of Colonial troops in the late war is instructive. Thus, in France the Senegalese, who are almost without tuberculosis in their native condition, and were found to be free from tuberculosis on reaching France, developed in large numbers an acute and fatal form of tuberculosis in spite of the hygienic measures enforced by the Army authorities.

This raises a curious point. If it were possible for any country to clear itself of the tubercle bacillus, it would appear to be incurring a great risk for an inhabitant to migrate into any neighbouring country.

But, in spite of this, it is the duty of medical men to keep in check, as far as possible, the ravages of the disease.

The preventive measures against tuberculosis at the present time are, in the first place, improvement in the general hygienic conditions. Thereby individual resistance—and communal resistance—can be remarkably increased.

In the second place, as every case of tuberculosis must arise from a previous case, either human or bovine, it is very necessary that methods of early diagnosis, preventive treatment, and segregation of the more infective types should be employed. This is done by the setting up of tuberculosis dispensaries, care committees, sanatoria, hospitals and colonies. These several elements are combined in the model Tuberculosis Scheme which is now universal throughout Great Britain.

In the third place, much can be done to anticipate and limit the progress of infection by the use of tuberculin, but caution is required in assessing the claims, sometimes hasty and extravagant, advanced by adventurers in this field of research.

Many other points might be brought forward, but the subject is such a vast one that I must content myself with drawing attention to the importance of a sound milk supply.

The contamination of our home herds with tuberculosis is so great that no pains should be spared to secure a safe milk supply, and I understand that the city of Toronto is a model in this respect.

The result of these methods of prevention against tuberculosis may be given briefly. Sir Robert Philip writes that in Scotland ten years before Koch's discovery the death-rate from this disease was 401 per 100,000;

in 1920 it had fallen to 124 per 100,000, a fall of 69·3 per cent. He also points out that the 'recent acceleration of rate of reduction which is noticeable in England and Scotland is of arresting interest.'

'In Scotland the acceleration of fall in the mortality rate likewise arrests attention. Thus, during twenty years up to 1890, the percentage fall in mortality from all forms of tuberculosis was 35, while during twenty years from 1900-1919 the percentage fall was 45.'

This is very satisfactory, and has only been arrived at by hard work on the part of medical men, nurses, and voluntary workers. Any Tuberculosis Scheme, however perfect in theory, will require untiring energy, patience, and perseverance to bear fruit. On this side of the Atlantic, in the United States, these anti-tuberculosis schemes have been pursued with enthusiasm, with the result that Washington in 1920 had a death-rate, from all forms of tuberculosis for 100,000 of the population, of only 85, Chicago 97, and New York 126. London in the same year had a death-rate of 127, practically the same as New York. Other nations have not been so energetic in preventive measures, Vienna having in 1920 a death-rate of 405 and Paris 279 per 100,000 from the same cause.

It is evidently the duty of every nation to take up arms against a disease which exacts such a terrible toll of death, suffering, and inefficiency. If this were done with energy and enthusiasm it is not too much to hope that in a few generations the tubercle bacillus would be practically brought under control, and with it many other malign influences.

INFECTIOUS DISEASES.—(B) PROTOZOAL.

I shall now pass on to the consideration of the second great group of infectious diseases, the Protozoal, and consider what methods of prevention have been found applicable to them.

The scientific study of the protozoal diseases of man may be said to have begun with the epoch-making discovery of the malaria parasites in 1880, by the illustrious Frenchman, Laveran; next, in 1893, the discovery by Theobald Smith and Kilborne of the cause of Texas fever and the part played in its dissemination by the cattle-tick; in 1894 the discovery of the trypanosome of nagana and its intermediate insect host the tsetse-fly; in 1898 the working out of the development of the malaria parasite of birds in the mosquito by Ronald Ross, greatly aided and abetted in the work by Patrick Manson, which led, through the work of Grassi and his fellow-workers in Italy, to the final solution of the malaria problem. A year later the important discovery of the mosquito carrier of yellow fever was made

by the American Army Commission, under the directorship of Reed, and in 1903 Leishman announced his discovery of the protozoal cause of kala-azar.

These protozoal diseases are world-wide, like the bacterial, but it is in the warmer climates that their effect is most felt.

The great plagues of the tropics, such as malaria, amœbic dysentery, kala-azar, and sleeping sickness among men, Texas fever, tsetse-fly disease, and others among domestic animals, are caused by minute microscopical animal parasites.

Large tracts of country have been and are still rendered uninhabitable to white settlers by their presence.

The opening up of Africa, for example, was rendered difficult by the tsetse-fly, before the advent of railways. No sooner had an expedition started for the interior than the fly attacked the cattle transport, and before long the expedition had to make its way back as best it could to its base on the coast. The only way to get into the country was on foot with native porters.

The protozoal diseases of domestic animals have also led to enormous loss in all parts of the world. Texas fever, or red-water, has swept whole countries of their cattle. After the Boer war, South Africa was devastated by the introduction of East Coast fever, another protozoal disease of cattle closely related to Texas fever.

How is the prevention of these diseases to be brought about? We find that up to the present little can be done by way of vaccination or inoculation or by the use of anti-sera as in the bacterial diseases. On studying the natural history of these protozoal parasites, however, it is found that many of them depend on an intermediate insect host for their continued existence, and it is by taking advantage of this characteristic that methods of prevention can be devised.

To illustrate this, I might cite the classical examples of malaria and yellow fever, but, as these must be familiar to you all, I shall take instead the trypanosome diseases of Africa, the best known of which are sleeping sickness in man and nagana or tsetse-fly disease in the domestic animals.

Nagana or Tsetse-fly Disease.

In 1894, a year after Theobald Smith and Kilborne had published their famous monograph on Texas fever, a severe epidemic among native cattle in the north of Zululand was reported to the Natal Government. The disease was called nagana by the natives, and it is curious that there

was no suspicion at the time that it had any connection with the tsetse-fly.

At this time a very enlightened administrator, the late Sir Walter Hely-Hutchinson, was Governor of Natal and Zululand, and it was due to him that the investigation of the cause of the Zululand outbreak was at once undertaken.

As I happened to be stationed in Natal at this time, I was chosen to undertake the work, and at once started on the long journey, mostly by ox-wagon, to the scene of the outbreak.

On examination of the blood of the nagana cattle, a minute active flagellated protozoal parasite, belonging to the genus Trypanosoma, was discovered, and after many experiments on dogs, horses, and cattle it was decided that in all probability it was the cause of the disease.

Trypanosomes had previously been described in the blood of rats and horses in India by Timothy Lewis and Griffith Evans, but nothing was known as to the mode of their transmission from animal to animal.

It seemed as if the discovery of the nagana trypanosome would have ended the investigation in Zululand without any means of preventing the disease being discovered, but another observation made at this time threw more light on the subject.

In the low country between the high ground, on which the nagana camp was situated, and the sea there happened to be a so-called 'Fly belt.'

Every schoolboy had read about the tsetse-fly in books of travellers and hunters, especially in those by the most famous of them all, David Livingstone the missionary, and out of curiosity I decided to find out what happened when an animal was bitten by the fly, or, as it was termed, fly-struck.

Natives were therefore sent with cattle and dogs into this 'fly country,' with orders to form a camp and expose the animals to the bites of the fly. This was done and it was with great surprise that on their return to the hill the blood of these fly-struck animals was found to contain the same parasite as that found in the nagana cattle.

Nagana and tsetse-fly disease were finally proved to be identical. The tsetse-fly disease was shown to be caused, not, as had been believed, by the poisonous bite of the fly, but by the transference of a protozoal parasite from the fly to the animal in the act of sucking blood.

Now the question arose as to where the fly found the parasite. As the tsetse-flies constantly lived among and fed on wild game, such as buffalo and antelope, these animals were suspected. Their blood was examined,

and before long it became evident that the wild animals acted as the reservoir of the disease, the trypanosomes living in their blood as harmless parasites. When the tsetse-fly fed on blood containing the trypanosome it became infected, and was capable by its bite of giving rise to a fatal disease in cattle, horses, or dogs ; whereas if it fed on a wild animal nothing happened, as the wild game are immune to the disease, much in the same way as the goat is immune to Malta fever.

Now that the natural history of the disease had been so far worked out it was evident that its prevention might be attempted.

This can be done in any of three ways : by getting rid of the wild game, the reservoir ; or by getting rid of the fly, the vector or carrier ; or, lastly, by removing the cattle, horses, and dogs to a safe distance from the 'fly country.'

This work on nagana led later, in 1903, to the discovery of the cause and mode of prevention of sleeping sickness.

Sleeping Sickness.

About the beginning of the century an epidemic of this disease raged round the shores of Lake Victoria in Central Africa. It had been introduced into Uganda from the West Coast, where it had been known for many years as a curious and unaccountable disease. It was observed that although the disease spread in a West African village from man to man apparently by contact, no such thing occurred among natives exiled from their homes. The disease never spread if introduced into native compounds in the West Indies or America, however closely the slaves might be herded together.

The disease remained shrouded in mystery and nothing had been done in the way of prevention, until the matter was taken up by the Royal Society of London in 1902 and a Commission sent out to investigate.

It is not necessary to go into details ; suffice it to say that after one or two false starts the Commission in 1903 came to the conclusion that the disease was caused, as in nagana, by a species of trypanosome.

The question of the distribution of sleeping sickness in Uganda was then taken up. This disclosed the remarkable fact that the disease was restricted to the numerous islands in the northern part of the lake and to a narrow belt of country skirting the shores of the lake. In no part of Uganda were cases found more than a few miles from the lake shore.

The next important step in the working out of the etiology was made when it was shown that the distribution of the disease was identical with

the distribution of the common tsetse-fly of the country, *Glossina palpalis*. Where there was no fly there was no sleeping sickness.

The problem was now solved. The epidemic could be stopped either by getting rid of the fly or by removing the natives out of the fly area. As the destruction of the fly was impracticable under the circumstances, the second method was decided on. The natives were moved from the islands and lake shore and placed on healthy inland sites, and the epidemic, which had cost the Protectorate some 200,000 lives, speedily came to an end.

This method of preventing disease, by removing man out of the zone of danger, is an extravagant one, and can only be done in exceptional circumstances. In Uganda the native population could be easily moved, but it meant that from about 1910 until the present day some of the most fertile land in Uganda has been lying derelict, has returned to the primitive jungle. The war delayed things, of course, but it is only now that the natives are being returned to their old homes on the islands and lake shore, in the hope that the fly by this time has lost its infectivity.

The other method, by the destruction of the tsetse-fly, has been carried out successfully in other places. For example, in the island of Principe, off the West Coast of Africa, by destroying the wild animals which supplied a large part of the food of the fly and by clearing the jungle the tsetse-flies disappeared, and with them the disease.

This is the method employed in malaria and yellow fever. It was by destroying the mosquito carrier that Gorgas drove yellow fever out of Havana and, later, both malaria and yellow fever from the Panama Canal Zone.

Thus through the work of Manson, Laveran, Ross, Reed, and others has it been made possible to deal with these two scourges of the tropics, malaria and yellow fever.

I include yellow fever among the protozoal diseases, although Noguchi in 1919 brought forward strong evidence that it is caused by a spirochæte.

In regard to yellow fever the victory has been almost won. During the last century this disease, known as 'yellow jack,' devastated the West Indies and Central and South America.

At the present time, thanks chiefly to the unremitting efforts of the late General Gorgas and the International Health Board of the Rockefeller Foundation, the disease has been driven out of the West Indies and Central America, and only retains a precarious foothold in Colombia and Brazil, whence it will doubtless be ejected during the next year or two.

One of the best examples of the prevention of disease is the attack made on yellow fever in Rio de Janeiro, the capital of Brazil, by the well-known scientist, Dr. Oswaldo Cruz, with the result that the annual deaths in the city from yellow fever fell from 984 in 1902 to 0 in 1909. This brilliant result was brought about by the destruction of the Stegomyia mosquito, the intermediate insect host in yellow fever.

So also in the case of malaria. A dozen years ago, based on the experience gained by Ross on the West Coast of Africa and Ismailia and by Watson in the Federated Malay States, the method of prevention by mosquito control and drainage has been so perfected that the practical blotting out of malaria from a given locality is now merely a matter of expense. A great deal of work has been done during the last few years in the way of experiment in the United States, and Vincent, the President of the Rockefeller Foundation, lately stated that there is evidence that 'under normal conditions an average community can practically rid itself of malaria at a *per capita* cost of from 45 cents to $1 per year.'

This is an altogether inadequate account of the methods of preventing these highly important protozoal diseases. From the few examples given, it will be seen that they are most rampant in warm climates, that they are as a rule conveyed from the sick to the healthy by an insect intermediary, and that it is by an attack on this insect, be it mosquito, tsetse-fly, or tick, that the best chance of success in prevention lies.

INFECTIOUS DISEASES.—(C) UNDETERMINED GROUP.

In addition to the bacterial and protozoal infectious diseases, there is a third and large class, known as the 'undetermined group,' in which the parasite is either unknown or doubtful. Many of these undetermined diseases are very common and familiar, such as influenza, measles, scarlet fever, smallpox, typhus fever, trench fever, dengue fever, and sand-fly fever; among animals, rabies, rinderpest, foot-and-mouth disease, and African horse-sickness.

The theory generally held at present in regard to most diseases included in this group is that the living germs causing them are ultra-microscopical, in at least some part of their life history, and this is strengthened by the fact that many of them pass through porcelain filters, which keep back the smallest of the visible bacteria. Hence the name, 'filter-passers.'

Many of these undetermined diseases are highly infectious and appear to infect at a distance through the air, as, for example, in influenza, scarlet fever, and smallpox.

In some of them there is no attempt made at prevention, except that the sick are isolated and placed under quarantine for a longer or shorter period. But in others there are well-known methods of prevention even when the virus is quite unknown. The best example is smallpox, the ravages of which have been completely held in check since the memorable discovery of Jenner. As has already been argued, this method of prevention, by inducing a mild or attenuated form of the disease, is at best a clumsy one, and when the natural history of the smallpox virus is better known it may be hoped that a more fundamental method of preventing this disease may be discovered. In the meantime the best means at our disposal is by the use of vaccine lymph, and people should recognise their responsibility to the community if through ignorance or selfishness they refuse to have their children vaccinated.

Another well-known disease with an unknown virus, rabies or hydrophobia, has also, by the genius and intuition of Pasteur, been robbed of many of its terrors. The mortality following bites of rabid animals has fallen from 16 per cent. to less than 1 per cent.

But in rabies, when the conditions are favourable, the radical method is to drive the disease altogether out of the country by the careful administration of muzzling and quarantine laws. This was carried out successfully in England at the beginning of the century.

Trench Fever.

There are among the diseases of undetermined origin a few which are slowly emerging from the unknown into the known. One of the most interesting of these is trench fever, which came into great prominence during the war.

The history of the investigation of this fever is interesting, and well illustrates the method of studying a disease with a view to its prevention.

Before the war, trench fever was unknown, though there is some evidence that it had been recognised at an earlier date in Poland and called Wolhynia fever. Be that as it may, it is quite certain that, though it was unknown on the Western Front at the beginning of the war, it is no exaggeration to say that it became one of the most powerful factors in reducing our man-power, probably more than a million cases occurring among the Allies on the Western Front. In 1917 in the Second British Army alone, out of a total of 106,000 admissions to hospital at least 20,000 of the cases were trench fever.

Although this fever has well-marked characteristics of its own, such as a peculiar type of temperature curve, and other symptoms, yet for a long time it was unrecognised as a separate entity, and remained mixed up with other diseases, such as typhoid fever, malaria, and rheumatism.

In 1916 MacNee, Renshaw, and Brunt in France made the first definite advance by showing that the blood of trench-fever cases was infective. They succeeded in transferring the disease to healthy men by the injection of the blood. The most careful microscopic examination of the blood corpuscles and lymph failed, however, to reveal any living germ.

Nothing more was done until the following year, when the British War Office took the matter up seriously and formed a Committee for the purpose of investigating the disease.

The United States of America, on coming into the war, at once recognised the importance of trench fever, and without delay also undertook its investigation.

In October 1917, at the first meeting of the Medical Research Committee of the American Red Cross in Paris, Major R. P. Strong recommended that a research into trench fever should be undertaken. He stated that, after several months' study of the problems relating to the prevention of infectious diseases occurring in the Allied Armies on the Western Front, it became evident that the subject of the method of transmission of trench fever was one of the most important for investigation in connection with the loss of man-power in the fighting forces.

At the next meeting, in November 1917, this was agreed to, and a Trench Fever Committee, under the chairmanship of Major Strong, was formed. The research was organised, and experiments begun on February 4, 1918. In less than six months the investigation was completed and the report in the hands of the printer. This is a striking example of research work which, if carried out at the beginning of the war instead of at the end, might have saved the Allied Armies hundreds of thousands of cases of disease, which, although never fatal, were often of long duration and led to much invaliding.

The most important result of the work of these two Committees was that it was amply proved that the louse, and the louse alone, was responsible for the spreading of the disease. This discovery meant that in a short time trench fever would have disappeared from our armies on the Western Front.

Just as the elimination of goat's milk blotted out Malta fever, the elimination of the mosquito malaria and yellow fever, so would the elimination of the louse have completely blotted out trench fever.

This method of prevention, by the destruction of the louse, although doubtless requiring careful organisation and energy in carrying out, was shown before the end of the war to be a perfectly practicable proposition, and there can be little doubt that, if the war had lasted much longer, trench fever, like tetanus, would have practically disappeared.

Besides the main discovery from the preventive point of view that the louse is the carrier, there are many other points of interest in the natural history of trench fever.

The living germ causing it has never been recognised in the human blood or tissues, probably on account of its extreme minuteness, and its consequent liability to confusion with other small granules.

But when the louse sucks blood from a trench-fever case there is apparently a great multiplication and development of the supposed micro-organism. In five to nine days the louse becomes infective, and there is seen in the stomach and intestines enormous numbers of very minute bodies. What the exact nature of these bodies is, is unknown, but there can be little doubt that they are the infecting agents by which the louse passes on the disease. They pass out in countless numbers in the droppings or excreta of the louse, and it is to these bodies in the excreta that infection is due. The louse seldom if ever gives rise to the disease in the act of biting. It is the infective excreta thrown out on the skin which causes the infection. The micro-organisms or so-called Rickettsia bodies contained in the excreta find their way into the blood through abrasions or scratches, and so give rise to the fever.

From what has been said it will be seen that trench fever is an interesting disease. It also explains why it disappears in times of peace. As soon as the war was ended, and our men could leave the trenches and resume their normal habits, the disease disappeared. The louse was eliminated and the trench fever with it.

Typhus Fever.

Another disease of the undetermined group closely related to trench fever and also carried by the louse is typhus fever, one more of the furies following on the heels of war. The French and British Armies escaped this scourge to a great extent, but some of the other countries, such as Serbia, Bulgaria, and Poland, were not so fortunate. It is stated that 120,000 Serbians died of this disease during the war, and it was only after vigorous steps had been taken in sanitary measures directed against the louse that the epidemic was got in hand.

After the long, exhausting Napoleonic wars, with the resulting poverty and destitution, typhus fever was prevalent in Great Britain and Ireland. About the middle of the century the improved economic conditions gradually led to the disappearance of the disease in Britain, although cases still occur in some parts of Ireland.

It is to Nicolle that we owe the advancement in our knowledge of this important disease. His work in Tunis on this subject dates from 1909. He showed that the blood of typhus cases is infective to monkeys, and, most important of all, that the infection takes place through the body louse. Just as in trench fever, the louse becomes infective after some five days, and it has been shown by the late Arthur Bacot of the Lister Institute that the excreta is also infective.

The minute bodies found in the typhus louse are, subject to some differences, very similar to those found in the trench-fever louse and have been named *Rickettsia prowazeki* by Rocha Lima. What group these bodies belong to is still a matter of discussion. Some consider them to be protozoa, with an ultra-microscopical stage in man and a developmental stage in the louse, while others look on them as minute forms of bacteria.

Although there is still some doubt as to the pathological significance of these Rickettsia bodies, the work of Sargent, Rocha Lima, Arkwright and Bacot, Wolbach, Todd and Palfrey has done much to establish a causal relationship between them and these two diseases, typhus and trench fever.

From the point of view of prevention, the important fact is that the infection is carried by the louse, and in the next great war it will be almost as necessary to prepare means for the destruction of the lice as of the enemy.

Rocky Mountain Fever.

A third disease belonging to this interesting little group—Rocky Mountain fever—occurs in certain localities in the United States. It provides another instance of a virus transmitted by an invertebrate host to man. As the result of the work of Ricketts and of Wolbach the wood-tick, *Dermocentor venustus*, is now recognised as the vector. Rickettsia bodies closely resembling those found in association with typhus and trench-fever virus have been shown to be present in the stomach and tissues of the tick, and the same bodies have also been demonstrated in the tissues of infected guinea-pigs.

Another interesting disease of the undetermined group is sand-fly fever, the virus of which is conveyed from man to man by the sand-fly. A

new era in its study has been opened up by the work of Whittingham and Rook, who have learned how to handle, breed, and keep sand-flies in captivity, and have shown that the virus is transmitted from generation to generation of flies without intervening passage through man or other higher animal. The knowledge of the life history of the flies will no doubt lead in due course to the suppression of the disease.

Another type of invertebrate vector is the Kedani mite, *Trombicula akamushi*, which transmits the virus of Japanese river-fever to man from wild animals. The dangerous character of this disease (Tsutsugamushi) and the minute size of the mite together have presented great difficulties to the Japanese investigators. Protection from the mite by special clothing and bathing after exposure to risk of infection are at present the most hopeful methods of prophylaxis.

Antitoxic sera have also been used with some measure of success in the prevention of diseases of this group. Degkwitz and others in Germany are reported to have been very successful in protecting children from measles and scarlet fever by injecting them with a small quantity of serum from convalescent patients. This method has also been found very useful under suitable conditions to protect cattle from foot-and-mouth disease.

But far more hopeful than protection by serum alone is the use of a vaccine to produce a lasting immunity, combined with antitoxin to prevent the vaccine from producing unpleasant results—the so-called toxin-antitoxin method. Most of the diseases for which this method of prophylaxis has proved valuable have been diseases of animals, such as pleuro-pneumonia of cattle, rinderpest, and foot-and-mouth disease; but quite recently the method of Dick, of Chicago, in scarlet fever has been supported by a number of observations. The system of testing and producing immunity is planned on the same lines as the Schick method for diphtheria.

DIETETIC DEFICIENCIES.—DEFICIENCY DISEASES.

The preceding account is but a short and meagre history of the marvellous advance which has been made in the prevention of infectious diseases in our times, an advance due in great part to the work of two men, Pasteur the Frenchman and Koch the German; those who have come after them have merely followed in their footsteps, been their disciples.

Time will not permit even to touch upon the advances made in the prevention of other important diseases, such as the surgical infections and

those caused by intestinal parasites, prominent among which are the hookworms and bilharzia.

This advance has not been limited to the infectious group : it has been shared by other groups, notably those due to dietetic deficiencies, the so-called deficiency diseases. These deficiency diseases are just as important, or even more important, than the infectious, since they are always with us and exact an enormous toll in lowered health, lowered vitality, malformation, and inefficiency.

Until a few years ago it was taught in the schools that a complete diet consisted of certain proportions of proteins, carbohydrates, fats, and salts. But our knowledge is constantly increasing, our ideas about things constantly changing, and what is looked on to-day as absolute immutable truth to-morrow is seen in the light of some newer knowledge to be but a crude beginning. So the teaching concerning what constitutes a complete and healthy diet has changed, inasmuch as certain substances have been discovered in food-stuffs in the absence of which an adequate number of calories supplied in the form of proteins, carbohydrates, fats, and salts can alone neither promote growth nor support life indefinitely. These accessory food factors, or vitamins as they have been named, are present in such minute quantities in foods that they have never been isolated, and their chemical composition is therefore unknown. It is still a matter of opinion as to whether they really constitute parts of the structure of living tissues, or whether they merely act as catalysts or stimulators in the processes of growth and metabolism. That they are definite chemical substances which can be added to or removed from a food-stuff, with good or evil results, has, however, been abundantly proved.

The untutored savage living on the natural fruits of the earth and the chase knows no deficiency diseases. It is only when man begins by artificial means to polish his rice, whiten his flour, and tin his beef and vegetables that the trouble begins. Civilised man living in comfort, drawing his food supply from the whole earth and able to vary his dietary at will, is in little danger ; but it is otherwise with children and adults living under institutional conditions, with armies on active service, encountering extremes of climate, and with young infants on their naturally restricted diet. While it is true that deficiency diseases will only develop to their well-marked dangerous stage if the deficiency of accessory factor is severe and protracted, a slighter deficiency, if prolonged, may cause a condition of general ill-health and inefficiency not less important although ill defined and difficult to diagnose. This fact is of special importance in the case of infants and young children.

The Discovery of Vitamins.

At the present time, three, and possibly four, distinct vitamins have been described and studied, and it is probably only a matter of time for others to be discovered.

The discovery of vitamins dates to the middle of the 18th century. In 1747 James Lind, a surgeon in the British Navy, carried out a series of experimental observations upon sailors suffering from scurvy, the conception and performance of which were entirely admirable. By appropriate control experiments he showed that the medical means in vogue for the treatment of the disease were futile, when not harmful, but that orange and lemon juices were a specific cure. Lind attempted to ascertain the relative anti-scorbutic value of various fruits and green vegetables, but was unable to observe a 'superior virtue' in one rather than in another. He confirmed Kramer's observations made at the beginning of the 18th century, during the war between the Turks and the Holy Roman Empire, that dried vegetables were useless, and adopts the explanation of his friend Cockburn 'that no moisture whatever could restore the natural juices of the plant lost by evaporation,' which Cockburn imagined were 'altered by a fermentation which they underwent in drying.'

Lind was struck with the beneficial effect of cow's milk in the treatment of scurvy. He explained it on the supposition of the milk 'being a truly vegetable liquor, an emulsion prepared of the most succulent wholesome herbs.'

Lind applied himself to the applications of these discoveries for the prevention of scurvy in the Navy, and recommended lemon-juice concentrated to a syrup by evaporation to be carried in all ships and served out to the sailors.

By the beginning of the 19th century the carriage of lemon-juice was made compulsory, first in the Navy and subsequently in the mercantile marine, with the result that the ravages of scurvy were prevented. With the advent of steam traction, too, the length of voyages was curtailed and supplies of fresh provisions were obtained at more frequent intervals. Scurvy became rare, and the medical profession, being no longer faced with this disease of dietary deficiency, soon forgot the significance of Lind's discoveries.

Before leaving this subject a curious fact may be related. The lemon-juice supplied to the Navy was at first made from lemons grown in Spain and the Mediterranean countries. Afterwards, when England took over

the West Indies, it was made from the lime, and scurvy again broke out. The reason of this is now known to be that whereas the lemon is particularly rich in anti-scorbutic vitamin, the lime is correspondingly poor.

The scientific study of the disease may be said to have lapsed for a century and a half, until Holst and his co-workers in Copenhagen investigated the etiology of scurvy anew on modern lines, with the help of experiments on animals. Their work, published in 1907 and 1912, formed the basis for the numerous researches carried out in England and America during and since the recent war. As a result of this work the etiology of scurvy, discovered in effect centuries earlier, has been firmly established as due to lack of a specific, undetermined, and as yet unisolated, constituent of fresh foods, especially of fresh vegetables and fruits, now known as Vitamin C.

In the meantime the existence of a second vitamin, the so-called anti-beri-beri, or anti-neuritic vitamin, Vitamin B, had been discovered. Eijkman's admirable studies at the end of last century, in 1897, on the etiology of beri-beri in the Dutch Indies brought forward evidence for the view that this disease was of dietetic origin, and was caused by a diet consisting too exclusively of highly milled and polished rice. He showed that the disease could be prevented if the outer layer (or pericarp) and the embryo of the seed, which had been removed in the process of milling, were restored to the 'polished' rice. Eijkman's discovery of the analogous disease in birds, *Polyneuritis gallinarum*, provided the necessary tool for further investigation of the subject. The researches of Grijns and others showed that the bran and polishings of rice were only one of many rich natural sources of the unknown principle preventing beri-beri, and it became evident that, while the disease is usually confined to tropical races subsisting largely on rice, the European white-bread eater is protected only by the varied diet he usually enjoys. Experience on active service shows that beri-beri may really develop on a diet of tinned meat and white bread or biscuit.

During the late war two examples of the use made of this new knowledge occurred in Mesopotamia. At the beginning of the campaign, on account of a difficulty in transport, there was a shortage of fresh food, with the curious result that scurvy broke out among the Indian troops and beri-beri among the British. The Indians were living on dried pulses, such as peas, beans, and lentils; the British on tinned beef and biscuits. The former diet was deficient in the anti-scorbutic vitamin on account of the complete drying of the seeds; the latter in the anti-beri-beri factor on account of the use of white flour from which the germ had been removed.

Some years ago it had been discovered that if dried seeds are germinated, a quantity of the anti-scorbutic vitamin is produced by the act of sprouting. This was done. The dried peas and beans were soaked in water and then spread out in shallow layers, to cause them to sprout, which they readily did in the warm climate. The germinated seeds were then issued to the Indian troops and cooked in the usual way. As a result of this simple procedure the scurvy completely disappeared.

In regard to the British troops it was known that the anti-beri-beri vitamin is contained in large quantities in certain cells, and notably in yeast cells. A small quantity of this substance in the form of marmite was added to the soldier's diet of bully-beef and biscuits, and the beri-beri in like manner disappeared.

It may seem strange that the conception of the rôle of vitamins in nutrition should have come first from the pathologist, and should not have emerged from the important advances in our knowledge of the physiology of nutrition which were made during the second half of the last century. The physiologists were preoccupied with the chemical composition of food-stuffs and their value for supplying energy and supporting growth, and with the necessity for supplying the requisite number of calories in a diet, distributed appropriately among proteins, fats, and carbohydrates, with adequate selection of mineral salts. It was only when these researches led to experiments in which animals were fed upon various mixtures of purified food elements that the investigators in this field began to realise that their repeated failures to rear animals upon such carefully arranged diets were not due to accident. The truth was suspected by Lunin in 1881, but it was not until 1912 that Hopkins published the classic experiments which proved the fact beyond a doubt. In the course of work along the same lines in the United States, McCollum and Davis in 1915 rediscovered Vitamin B, and, in addition, a third essential dietary constituent, a fat-soluble vitamin, present in butter-fat and certain other fats of animal origin, especially in cod-liver oil and other fish oils. This vitamin is known as fat-soluble Vitamin A.

Rickets as a Deficiency Disease.

The discovery of the fat-soluble vitamins proved to be of great importance in elucidating the etiology of this disease, which had for long been an unsolved problem. Some authorities had erroneously considered it to be an infectious disease, like tuberculosis. Another school held the so-called Domestication Theory, that it was caused by unnatural surroundings, involving a want of sunlight, fresh air, and exercise. A third considered

rickets to be caused by improper feeding, though opinions differed as to the exact nature of the dietetic defect. The conclusion, first put forward by Mellanby in 1918, that a deficiency of fat-soluble vitamins plays a most important part in the causation of the disease is now generally accepted. This has been established by a large amount of work, both experimental and clinical, carried out by Mellanby himself, McCollum and Hess and their respective co-workers in the United States, and Korenchevsky and others in England. It may be laid down that if a young animal is supplied with a sufficiency of these vitamins, rickets will not develop. The question of prevention is therefore one of economics. The difficulty is that these fat-soluble vitamins are chiefly found in such food-stuffs as butter, eggs, the fat of beef and mutton, and fish oils, all expensive articles of diet which the poorer classes can seldom afford. The only 'butter' used by them is probably some form of margarine, made from vegetable oils which contain little or no anti-rachitic vitamin. The question of prevention is for the sociologist. Science can only discover the causes and point the means. It is for governments and local authorities to carry out preventive measures in practice, and it is to be feared that science is often far ahead of the community in its share of the work.

Although the theory that rickets is an infectious disease has been exploded, a great and remarkable truth was contained in the domestication and hygienic theories which held that, among other unhygienic conditions, want of sunlight was concerned in the etiology of the disease. During the last five years it has been discovered that exposure to sunlight or to the ultra-violet rays of the mercury vapour quartz lamp can cure rickets in children. Experiments on animals have shown that the effective rays in the sunlight are also the ultra-violet. This discovery has indicated lack of sunlight during winter as one factor concerned in the large spring incidence of the disease in industrial cities in northern climates.

A complete and well-controlled research showing the interaction of diet and light in the prevention and cure of rickets in infants was gained in Vienna, since the war, by Dr. Harriette Chick of the Lister Institute and her four colleagues. There the curious fact came to light that infants fed on a diet deficient in anti-rachitic vitamin developed the disease only in winter and not in summer, and, moreover, could be cured in winter by exposure to artificial forms of radiation or by administration of cod-liver oil without any other change in diet or management. Another set of children who had a sufficient supply of fat-soluble vitamins in their diet, in the form of cod-liver oil, escaped the disease altogether.

Experiments on rats have also shown that in animals fed on a rickets-producing diet, rickets does not occur if the rats are exposed regularly to sunlight or to the rays of the mercury lamp, or other form of artificial ultra-violet radiation ; whereas if they are kept in the dark, rickets does develop. If, on the other hand, the diet is complete in all respects, including abundance of fat-soluble vitamins, the animals do not develop the disease, even if kept constantly in the dark.

How this is brought about is not known. At one time it was thought that the action of the ultra-violet rays on the tissues might enable the animal to synthesise fat-soluble vitamins, as it does in the tissues of plants, but recent evidence brought forward by Miss Margaret Hume in Vienna, and by Goldblatt and Soames at the Lister Institute, suggests that light can neither create nor act as a substitute for the vitamin. It seems rather to act as a stimulant, enabling the animal to make full and economical use of its store of fat-soluble vitamins, and when the store is used up growth ceases in spite of the continued action of the rays.

An important and practical point in regard to the connection between diet and sunlight and the formation of the anti-rachitic vitamin is the relation to cow's milk. Recent work carried out by Dr. Ethel Luce at the Lister Institute has shown that milk obtained from a cow on pasture in summer contains a sufficiency of the growth-promoting and anti-rachitic fat-soluble vitamins. In winter, on the other hand, if the cow is stall-fed and kept in a dark stable, the milk may become deficient in these respects and young animals fed on it may become rachitic. This work shows that the seasonal variation in quality of the cow's milk may be an additional factor in the seasonal incidence of infants reared upon it. It also disposes of the idea, very current in some quarters, that cow's milk possesses low and negligible anti-rachitic properties and that the anti-rachitic properties of cod-liver oil are specific and peculiar to that substance.

Enough has been said to show that rickets may be regarded as a disease of sunless houses combined with a diet deficient in the anti-rachitic vitamin, and the means of prevention are sufficiently obvious, if not always easy and simple to carry out.

Doubtless in the future this new knowledge in regard to the accessory food factors in diet will be used to a greater extent than it has been up to the present, in which case it is not too much to expect that the city children of some future generation will have better-grown bodies and stronger, healthier teeth than their predecessors of the pre-vitamin age.

This might be attained in a comparatively near future if only man could be allowed to work out his salvation in peace. Instead of this, great wars come and throw back the work for generations.

To saddle the country with a million and a half of unemployed, with the consequent poverty, insufficient food, clothing and housing, is not calculated to further the prevention of disease and raise the standard of health. Is it too much to hope that in the revolving years a time may come when by a Confederation or League of Nations the world may be so policed that no one country will be able with impunity to attempt the destruction of its neighbour? Until this happens it is difficult to see how rickets, tuberculosis, and other diseases can be adequately dealt with in our city populations.

DISEASES DUE TO DUCTLESS GLANDS.

I can only briefly allude to the astonishing advance in our knowledge of the diseases caused by a defect or excess of secretion of the ductless glands. Many of these discoveries are among the fairy tales of science.

All this advance has taken place in the comparatively short space of time under review.

Professor Starling, one of the chief protagonists in this advance, in his Harveian Oration a year ago states this very vividly: 'When I compare our present knowledge of the workings of the body, and our powers of interfering with and of controlling those workings for the benefit of humanity, with the ignorance and despairing impotence of my student days, I feel that I have had the good fortune to see the sun rise on a darkened world, and that the life of my contemporaries has coincided not with a renaissance but with a new birth of man's powers over his environment and his destinies, unparalleled in the whole history of mankind. Not but there is still much to be learned: the ocean of the unknown still stretches far and wide in front of us, but for its exploration we have the light of day to guide us; we know the directions in which we would sail, and every day, by the co-operation of all branches of science, our means of conveyance are becoming more swift and sure. Only labour is required to extend almost without limit our understanding of the human body and our control of its fate.'

There is one point of likeness between the vitamins which we have been considering and these glandular secretions, or hormones, as they are named. Just as we have seen that the presence or absence of an extremely minute

quantity of a vitamin may determine growth and health or disease and death, so an extremely minute quantity of glandular secretion may have a similar effect.

The anterior lobe of the pituitary gland is a very small body, yet an excess of its secretion will cause a child to grow into a giant ; a deficiency, and the growing child will remain an infant.

The best known of the ductless glands is the thyroid, and the effect of its secretion is truly marvellous. A deficiency, and the child grows up a heavy-featured, gibbering idiot. Rectify the supply of thyroid secretion : the heavy features disappear, the eyes brighten, the intelligence returns, and instead of the former heavy-jowled imbecile you have a bright, happy and normal schoolboy.

On the other hand, if there is an excess of the thyroid hormone, exophthalmic goitre, or Graves's disease, is the result. Remove the redundancy and health returns.

The active principle of the thyroid has lately been shown to be a compound containing iodine. If there is no iodine in the soil or water, goitre is the result, as in parts of Switzerland, Canada, and the United States. This aspect of the subject was taken up some ten years ago by Dr. David Marine and his colleagues at Cleveland, Ohio. They find that endemic goitre may be prevented by the simple method of giving for a time minute doses of iodine, and conclude that with this simple, rational, and cheap means of prevention, this human scourge, which has taken its toll in misery, suffering, and death throughout all ages, can and should be controlled, if not eliminated, and look forward in imagination, a few generations hence, to the final closing of the chapter on endemic goitre and cretinism in every civilised nation in the world.

Many advances have also been made in our knowledge of the function and uses of other ductless glands, and, as you know, the latest victory in this field is the discovery of insulin and the successful treatment of severe diabetes, for which magnificent work your own townsmen Banting and Best deserve the highest honour.

In many other directions than those touched upon has there been progress in the prevention of disease. It would take more than one address to describe the activities of the Rockefeller Foundation alone. Campaigns for the relief and control of hookworm disease, malaria control, the eradication of yellow fever, anti-tuberculosis work and education are being pursued on such a scale and at such a lavish expenditure of money as to leave us in the Old Country breathless with admiration and envy.

This foundation, incorporated in 1913, was founded, in the words of the President, 'to stimulate world-wide research, to aid the diffusion of knowledge, to encourage co-operation in medical education and public health.' Its chartered purpose is to promote, not the exclusive prosperity of any one nation, but 'the well-being of mankind throughout the world.'

Science, indeed, knows no boundaries of nations, languages, or creeds. It is truly international. We are all children of one Father. The advance of knowledge in the causation and prevention of disease is not for the benefit of any one country, but for all—for the lonely African native, deserted by his tribe, dying in the jungle of sleeping sickness, or the Indian or Chinese coolie dying miserably of beri-beri, just as much as for the citizens of our own towns.

From what has been said it is abundantly clear that during the comparatively few years that have passed since this Association first met in Canada, enormous advances have been made in the prevention of disease. Before that time we were still in the gloom and shadow of the dark ages. Now we have come out into the light. Man has come into his heritage and seems now to possess some particle of the universal creative force in virtue of which he can wrest from Nature the secrets so jealously guarded by her and bend them to his own desire.

But let there be no mistake, much has been done but much more remains to be done. Mankind is still groaning and travailing under a grievous burden and weight of pain, sickness, and disease. Interruptions are sure to come in the future as they have in the past in the work of removing the incubus, but, in spite of these, it is the duty of science to go steadily forward, illuminating the dark places in hope of happier times.

SECTIONAL ADDRESSES.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

THE ANALYSIS OF CRYSTAL STRUCTURE BY X-RAYS.

ADDRESS BY

PROFESSOR SIR W. H. BRAGG, K.B.E., D.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

In this address I propose to consider the new methods of analysing the structure of materials by means of X-rays, considering especially the stages by which they move towards their objective. It is convenient to recognise three such stages, of which the first comprises the simplest and most direct measurements and the last the most indirect and complex.

The fundamental measurement of the method is the angle at which rays of a given wave-length are reflected by a set of planes within the crystal. The planes of a ' set ' are all exactly like one another : an imaginary observer within the crystal could not tell by any change in his surroundings that he had been moved from one plane to another. Sometimes there is no reflection of the first order from a set so defined, because the planes may be interleaved by other planes so spaced and of such strength as to annul the true reflection ; but this can always be allowed for. When the wave-length of the X-rays is known, the angular measurement can be used to find the spacing of the set of planes, and in this way a linear dimension of the crystal is measured. The spacing is the distance between any plane and its nearest like neighbour on either side. If the spacings of three different sets of planes are found, the volume of the unit cell is found. The crystal unit cell is bounded by six faces, each set of planes furnishing a pair. The pair consists of two neighbouring planes of the set. The cell may have a great variety of forms, but has always the same volume. The specific gravity of the substance being known, it is possible to find the number of atoms of various kinds which the cell contains : the proportion of the various kinds is necessarily the same as in the molecule of the substance. The cell is in practice found always to contain a small integral number of molecules, one, two, three, or four, rarely more. This assemblage of molecules is fully representative of the crystal ; by the mere repetition of the cell, without the addition of any new features, the crystal with all its properties is produced.

There are, therefore, three types of assemblage. The simplest is that of the single atom, as in helium in the gaseous state, in which the behaviour of every atom is on the whole the same as the behaviour of any other. The next is that of the molecule, the smallest portion of a liquid or gas which has all the properties of the whole : and lastly, the crystal unit, the smallest portion of a crystal (really the simplest form of a solid

substance) which has all the properties of the crystal. There are atoms of silicon and of oxygen : there is a molecule of silicon dioxide, and a crystal unit of quartz containing three molecules of silicon dioxide. The separate atoms of silicon and oxygen are not silicon dioxide, of course : in the same way the molecule of silicon dioxide is not quartz ; the crystal unit consisting of three molecules arranged in a particular way *is* quartz.

The final aim of the X-ray analysis of crystals is to determine the arrangement of the atoms and the molecules in the crystal unit, and to account for the properties of the crystal in terms of that arrangement.

The first step is the determination of the dimensions of the crystal unit cell : any one of the possible ways in which the cell can be drawn will do. When this has been completed it is a simple calculation in geometry to find the distance between any atom and any other atom in the crystal of like kind and condition, or, in other words, the distance an observer would have to travel from any point within the crystal to any other point from which the outlook would be exactly the same and would be similarly oriented. This is the only measurement which the X-rays make directly : any other measurement of distance is made indirectly, by aid of some additional physical or chemical reasoning. It is not possible by direct X-ray measurement to determine the distance between any two points—atom centres, for example—within the same cell.

Let us take an example. The crystal unit of naphthalene has the dimensions defined in the usual way by the statement :—

$$a=8.34\text{Å} \quad b=6.05\text{Å} \quad c=8.69\text{Å} \quad \beta=122°\ 49' \quad \alpha=\gamma=90°.$$

It contains two molecules : an integral number, as always. These facts are given directly by the X-ray measurements. But there is no direct determination of the distance between any carbon atom and any other carbon atom contained within the same cell : the measurements given are those of the distances between any atom and the nearest neighbours, in three principal directions, which are exactly like itself, these distances being the lengths of the edge of the cell. There is not even a measurement of the distance between the two molecules in the same cell, because they are not similarly oriented. In fact, there is no clear meaning in the term ‘ distance ’ in this case, just as we cannot state the distance between an object and its image in a mirror, unless the object is a point of no dimensions. If the molecule of naphthalene has a centre of symmetry, as is indeed indicated during the development of the results of the X-ray analysis, it is possible to state the distance between the centres of symmetry of the two molecules in the same cell, but this does not define the distance between any atom in one of the two molecules and any atom in the other. All such distances, if they are to be defined and measured, can only be found by the aid of fresh considerations.

Or again, let us take the case of rock-salt. The crystal unit cell of rock-salt contains one molecule : one form of the cell has for its eight corners the six middle points of the faces of a certain cube (edge=5.62 A.U.) and two of the opposite ends of any diagonal of the cube. The so-called face-centred cube is four times as large as the cell, and contains four molecules. The dimensions of the cell are determined directly by the X-rays, which

measure the distance between each of the three pairs of parallel faces that contain it. The cell may be placed so that each corner of it is associated in the same way with a molecule of sodium, let us say: and, of course, the knowledge of the dimensions of the cell is equivalent to a knowledge of the distance between any two sodium atoms in the crystal, which atoms are all alike in every respect. But we have no direct measurement by the X-ray methods of the distance between a sodium and a chlorine atom. We infer that the chlorine atom lies at the centre of the sodium cell, or *vice versâ*, from considerations of symmetry. Crystallographic observations of the exterior form of the cell assign to the crystal the fullest symmetry that a crystal can possess. If the cell that has been described is to contain the elements of such full symmetry, the chlorine atom must lie at the centre of it. It cannot lie anywhere else, for every cell would contain a chlorine atom similarly placed. There would then be unique directions in the crystal; that is to say, polarities. Moreover, both the sodium and the chlorine atoms must themselves contain every symmetry of the highest class: the full tale of planes of symmetry, axes of rotation, and so on. They both have centres, and we can state the distance between a chlorine atom and a sodium atom because we can state it as between centre and centre, and put it equal to half the distance between two sodium atoms on either side of the chlorine. The structure of sodium chloride is then determined completely.

It may possibly be a difficulty that the cell so described does not at first appear to have all the symmetries of the rock-salt cube, but it is to be remembered that we are to expect the full display of symmetries only when the cell has been repeated indefinitely in all directions. We may take a simple case as follows:

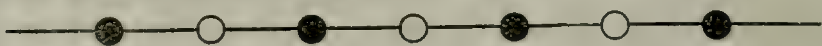


Fig. 1

Suppose sodium and chlorine atoms were to be arranged in a line as in the figure, just as they are in any of the three principal directions in the crystal. A plane of symmetry perpendicular to the line of atoms indefinitely prolonged may be drawn through the centre of any atom. The unit cell is one molecule: one chlorine and one sodium. The unit by itself has not this symmetry, but the repetition of the same molecule in either direction on either side provides the symmetry. Moreover, each sodium and each chlorine must itself have a plane of symmetry, and the planes are equally spaced. We can state the distance between a sodium and a chlorine atom as half the distance between two sodiums.

Let us take one more instance, the diamond. The crystal unit cell contains two atoms of carbon: as in the case of rock-salt, it may be so chosen that, of its eight corners, six are the middle point of the faces of a certain cube and two are the ends of any diagonal of the cube. The sides of this cell are determined by the X-rays, and are all equal to 2.52 A.U. This is the distance between any carbon atom and the nearest carbon atom which is exactly like itself. The distance between the two carbon atoms in the same cell is not measured directly, but can be inferred after it has

been defined. This we are able to do because the carbon atom is tetrahedral; a tetrahedron has a centre, and we can state the distance between the centres of two tetrahedra, no matter how the tetrahedra are oriented. We know that the carbon atom, as built into the crystal, is tetrahedral, because the X-ray observations show that four trigonal axes meet in it. The two atoms in the cell are oriented differently; one may be said to be the image of the other, if translation shifts are ignored, in each of the faces of the cube. Considerations of symmetry or X-ray observations show that the centre of an atom of the one orientation lies at the centre of a tetrahedron formed by four atoms of the other orientation. The edge of this tetrahedron is the edge of the unit cell, and its length is 2.52 A.U. It may then be calculated that the distance between the one atom and the others, its nearest neighbours, is 1.54 A.U. We may call this distance the diameter of the carbon atom, but we must remember our original definition of the meaning of the term. Thus the 2.52 A.U. is the result of a direct unaided X-ray measurement, but the 1.54 A.U. is not, and has no meaning except after special definition.

Only such distances between atoms as can be calculated from the dimensions of the unit cell can be measured directly and without qualification. The determination of these distances may be looked on as the result of the *first stage* of the analysis by X-rays.

We now come to a *second stage*. It is possible to make other statements of the relative positions of atoms and molecules which, though less complete and informative than those of distances, and their orientations, are necessary to the solution of the crystal structure problem. These also are deduced by means of the X-ray methods.

It often occurs that the atoms or molecules in one cell can be divided into two portions which are the reflections of one another across some plane, or can be brought to be the reflection of each other by a shift parallel to the plane. In that case the orientation of the plane and the amount of the shift can be stated definitely, the former by inspection of the crystal or by X-ray observations, the latter by X-ray observations alone. So also it may happen that the atoms or molecules in the same cell may be divided into portions which can be made to coincide with each other by a rotation round some axis with or without a shift parallel to that axis. The direction of the axis can be found by inspection of the crystal or by X-ray observations; the amount of the shift can be found by X-ray observations alone.

In these cases the distances that are found by the X-ray method are all that can be stated without special definition. It is not possible to state the distance between an object and its image in a mirror, if the object has any extension in space; but it is possible to state the magnitude of a shift.

Measurements of this sort constitute a characteristic feature of the X-ray analysis, for which reason I would like to discuss them briefly.

We know that it is possible to separate crystals into thirty-two classes, according to the kind of external symmetry which they display. As we have hitherto been unable to look into the interior of the crystal, we have been obliged to be content with this imperfect classification by outer appearance. It has been shown, however, that there is a classification by inner arrangement which is perfect and includes the other. It is beyond the limits of ordinary vision: out of the range of the lens and the

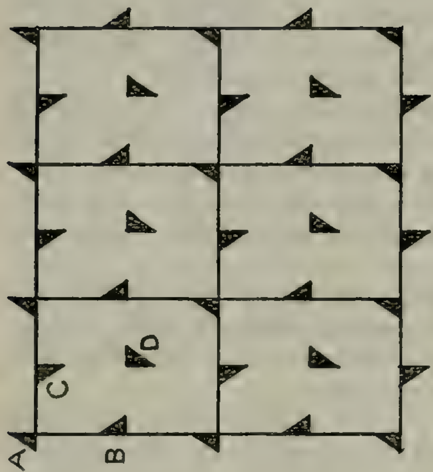


Fig. 4.

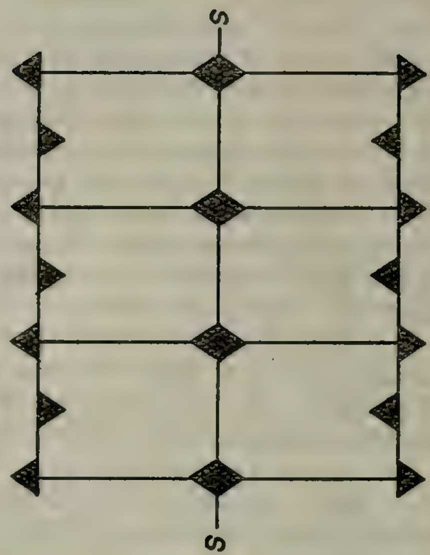


Fig. 3a.

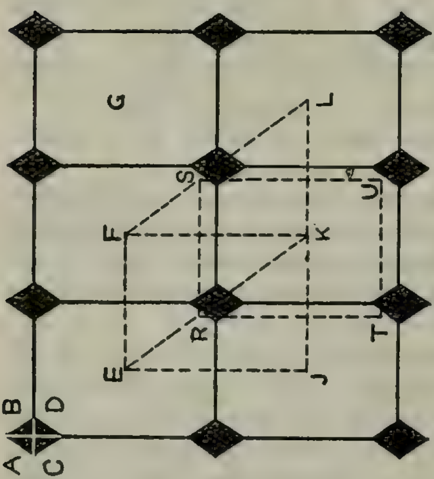


Fig. 2.

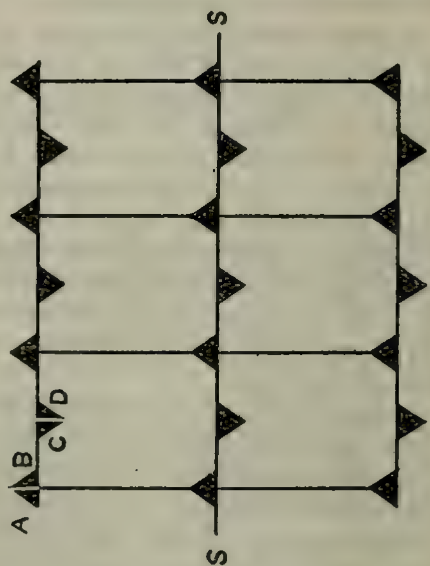


Fig. 3.

goniometer. The interior arrangements of the crystal, of which the outer form is one consequence, are so varied as to furnish 230 different modes. With very few exceptions the X-rays now allow us to carry the classification to this higher degree. If the modes are grouped according to the external features of the crystals that follow them, we come to the well-known thirty-two classes, there being several modes in every class. I may be permitted to illustrate this important point by examples, although it is familiar to those who have studied crystallography. Let us consider first a two-dimensional example, which is much easier to describe than the three-dimensional actuality, and contains all the essential ideas.

Consider an arrangement of figures in a plane which displays symmetry across two planes at right angles to one another. Such arrangement may be exhibited diagrammatically, as in fig. 2. The unit cell may be drawn in various ways, EFKJ, EFLK, RSUT, and so on. The cell contains, however it is drawn, either a whole diamond or enough parts to make up a whole diamond. Each diamond can be divided into four parts: B and D are the reflections of A and C across a plane; C and D are the reflection of A and B across a plane at right angles to the first plane. Unless the diamond, the content of one cell, could be divided in this way there could not be the double symmetry. But, granted this division into four portions, it is not necessary that the four should be arranged as in the figure in order that the double symmetry may be obtained. There are two alternatives (figs. 3 and 4).

In fig. 3 the lower half of each diamond—that is to say, the portions C and D—are shifted, whether to right or to left is immaterial, by an amount equal to one-half of one side of the cell EFKJ. The symmetry about a vertical line in the plane of the paper is obviously retained. It is not so obvious that there is still any symmetry about the horizontal line until we realise that we mean only 'observable symmetry': that which is to be seen in the outer form of the indefinitely extended figure, corresponding to the crystal. Clearly, the whole figure will present the same appearance from below as from above. In fact, we can see that as a whole the lower part of the figure is symmetrical with the upper part by imagining the upper and the lower to be further shifted relatively as in fig. 3A: the two parts sliding on one another along the line SS. The two parts are then the image of each other across SS in the full sense of the word.

From fig. 2 we may also realise that the amount of the original shift must be equal to one-half of EF: no other shift will give the symmetry which fig. 3A shows. In figs. 5 and 5A a different shift has been given, and the failure is clear.

In fig. 4 not only are C and D shifted parallel to the horizontal line, but also B and D are shifted parallel to the vertical; this time the amount of shift is one-half of the side EJ.

The three modes of figs. 2, 3 and 4 all lead to the same external symmetry. There is one more which is based, as we should say, on a different lattice and is symmetrical, like the others, about two lines at right angles to each other. It is shown in fig. 6. There are no variations of fig. 6, as of fig. 2, to be obtained by the introduction of shifts. If in fig. 6 we shift C and D relatively to A and B, as we did in fig. 3A, we find that they can now be described as the direct reflection of A′B′ into CD and of A′C into B′D, and the mode of fig. 6A is the same as that of fig. 6.

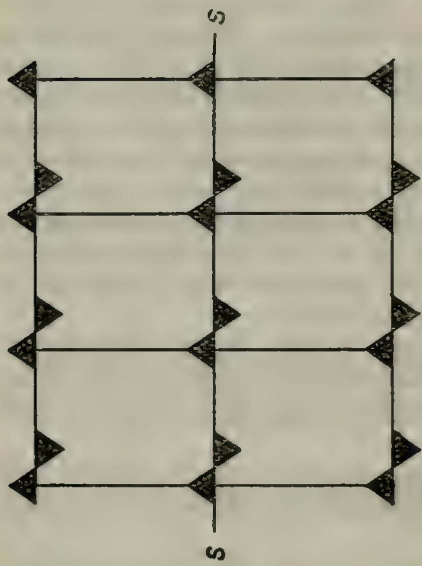


Fig. 5.

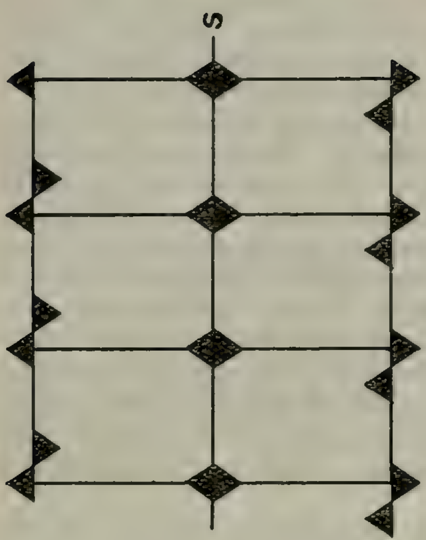


Fig. 5A.

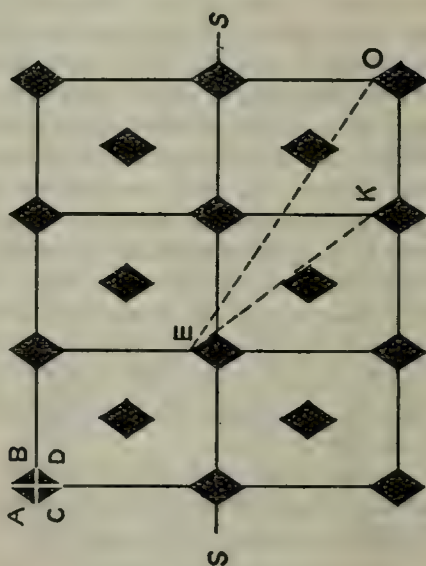


Fig. 6.

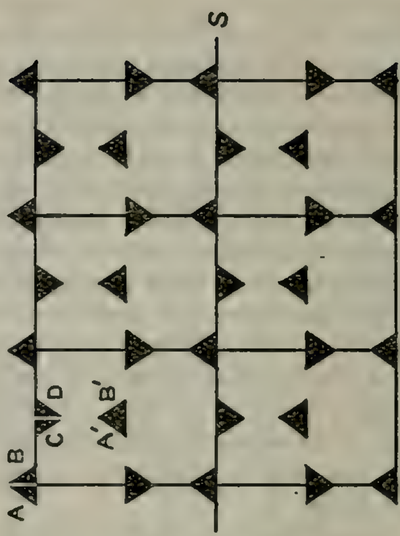
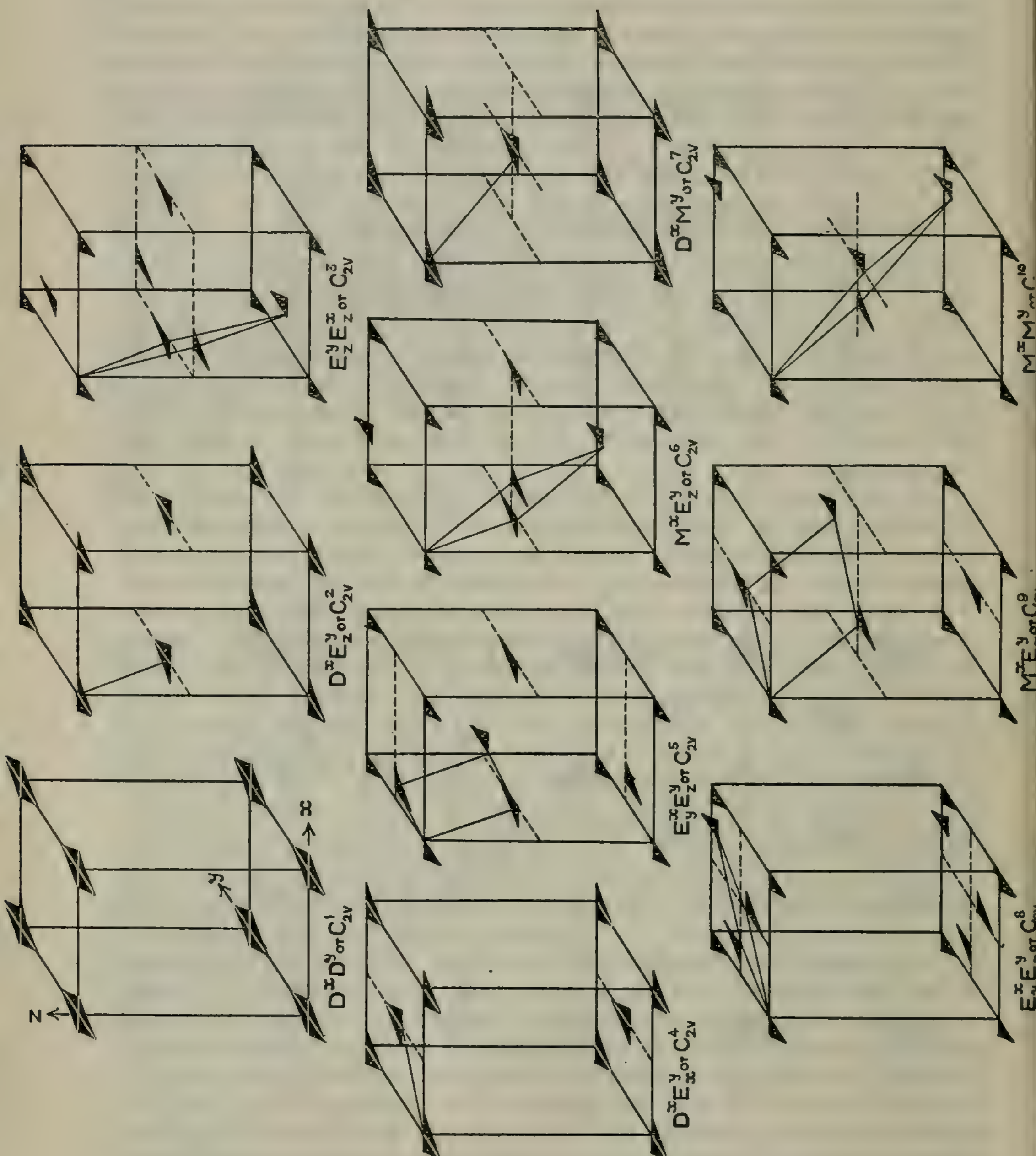


Fig. 6A.

There are therefore four *modes* in one *class*: four varieties of internal arrangement which all lead to the same external appearance of symmetry.

Our example is two-dimensional, and the crystal has three dimensions. But there are no new ideas to be added: it is only the numbers of symmetries, modes, and classes that are increased. If, for example, we continue the study of the modes of arrangement that lead to an external symmetry of reflection across two planes at right angles to each other, we find that there are four lattices instead of two, and twenty-two modes instead of four. The class containing crystals that possesses this particular form of symmetry is generally called the 'hemimorphic class in the orthorhombic system.' Its symbol is C_{2v}: the symbols of the four lattices are Γ_J Γ_0' Γ_0'' Γ_0'''. In every case the content of the unit cell is divisible into four parts, corresponding to the ABCD of figs. 2 to 6. The ten modes in the Γ_0 lattice are shown in fig. 7, which will serve to show the numerical increase due to the introduction of the third dimension. Under each separate figure is given, beside the crystallographic symbol, another symbol which describes the shifts: D^x means a direct reflection across a plane parallel to yz; E^x_y a reflection across a plane parallel to yz, together with a shift parallel to the axis of y equal to half the y edge of the cell, and M^x a reflection across a plane parallel to yz, together with a shift parallel to the diagonal of the yz face and equal to half that diagonal.

Let us now see how the X-ray analysis distinguishes the mode. Let us imagine that fig. 2 represented a number of pits in a plane reflecting surface. The surface could be used as a grating having many spacings instead of one. If, for example, we so placed it that the horizontal lines of the figure were parallel to the slit of the spectroscope the spacing would be equal to EJ: if the vertical, the spacing would be equal to EF. Again, if the grating were so placed that EK, for example, were vertical, the spacing would be the perpendicular distance between EK and FL. If the surface is pitted as in fig. 3, the spacing when the horizontal line is parallel to the slit is the same as before; but when the vertical is parallel to the slit the effective spacing is only half what it was in fig. 2. This follows from the fact that if we divided the surface into a number of vertical narrow strips the diffracting effect of each such strip, for this position, depends on the total amount of reflecting surface contained in the strip, but not on its distribution along the slip. It does not matter that C and D are upside-down as compared to A and B. The strata consisting of C and D portions have interleaved the strata of A and B portions. This halving of a spacing of fig. 3 as compared with fig. 2 occurs only when the grating is placed so that the slit is parallel to the vertical line of fig. 3, and not when any other line is vertical, except by some odd chance connected with the shape of the pits. In this way it is possible to distinguish between fig. 2 and fig. 3. The mode shown in fig. 4 is distinguished by the halvings of both the horizontal and vertical spacings, and of no others. In the case of fig. 6, as compared with fig. 1, the spacing is halved when the slit is parallel to the horizontal or the vertical line of the figure, and also whenever the grating is so placed that the parallel to the slit passing through one of the corners of a cell does not pass through the centre of that or any other cell, as, for example, if EO but not EK is parallel to the slit. It is therefore easy to distinguish each of the four modes.


D^xD^y or C_{2v}^1
$D^xE_z^y$ or C_{2v}^2
$E_z^yE_z^x$ or C_{2v}^3
$D^xE_x^y$ or C_{2v}^4
$E_y^xE_z^y$ or C_{2v}^5
$M^xE_z^y$ or C_{2v}^6
D^xM^y or C_{2v}^7

Similar methods are applicable to the three-dimensional crystal. If, for example, we consider the case of C_{2v}^{2} or $D^{x}E_{2}^{y}$ we can show that, whereas in general the spacings of planes are such as are proper to a cell of the dimensions and form drawn in the figure, all planes of the form $lx/a+mz/c=$an integer, show halved spacings, unless l is odd and m is even: which is sufficient identification of the mode of arrangement. The symbols a and c denote edges of the cell.

If we follow this line of reasoning through all the thirty-two classes, we end, of course, with the discovery of the 230 modes which are known to exist: and with the identification marks of each, with certain qualifications. These last are of two kinds. One of them is general in nature and is a consequence of the fact that the X-rays can measure only the distance between two like points in neighbouring cells, say A and B. But they do

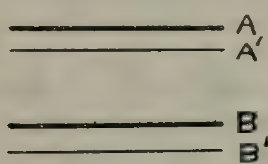


FIG. 8.

not indicate any difference that may exist between AB and BA. If such a difference exists it may be expected to show in the external characteristics of the cell, giving it polarity. A good example is to be found in zinc blende. Layers of zinc and of sulphur atoms alternate with one another as in fig. 9, all of them being perpendicular to a trigonal axis of the crystal. The distance between a zinc atom in the layer A to a zinc atom in the layer B is found without question by the X-ray method. Now we know from observation of the crystal that there is a difference between AB and BA: the crystal is polar. A crystal plate cut so that its faces are perpendicular to the axis shows different properties on its two sides: if heated, one face becomes positively and one negatively electrified. Whichever face we use in the X-ray spectrometer we obtain the same value for the spacing, and we find ourselves unable to detect any difference between the two aspects by means of the spectrometer observations.

We may see this point in another way. Suppose that fig. 9 represents a section of a crystal consisting of two kinds of atoms, indicated respectively by full and empty circles. The arrangement clearly has no symmetry about a vertical line in the plane of the paper. But if X-rays were incident from above, as shown there would be equal reflections from the planes 11′ and 22′. If the incident rays were heterogeneous and a photographic plate were placed to receive the Laue reflections in the usual way, there would be a symmetry distribution of spots on either side of A, although there is no symmetry in the crystal to correspond.

It is only when we have taken other considerations into account and have determined the structure that we can establish the polarity of the crystal. We may take, for example, the fact that zinc blende is cubic, and therefore has four trigonal axes, a fact which we may discover from X-rays as well as from the external form. Also, the unit cell contains only one molecule of zinc sulphide, and may be drawn of the same form as in diamond: that is to say, its eight corners can consist of the six centres

of cube faces and the two ends of a diagonal. If we put zinc atoms at the corners of the unit cell, the sulphur atom must lie either at the centre of the unit cell or at the centre of the regular tetrahedron formed by four of the corners of the cell: only by the adoption of one of these alternatives do we get the four trigonal axes. The former gives the rock-salt structure and is distinguished by the fact that the (100) and (110) spectra decrease regularly in intensity from lower to higher orders, whereas in the (111) spectrum the even orders are relatively greater than the odd. In the latter

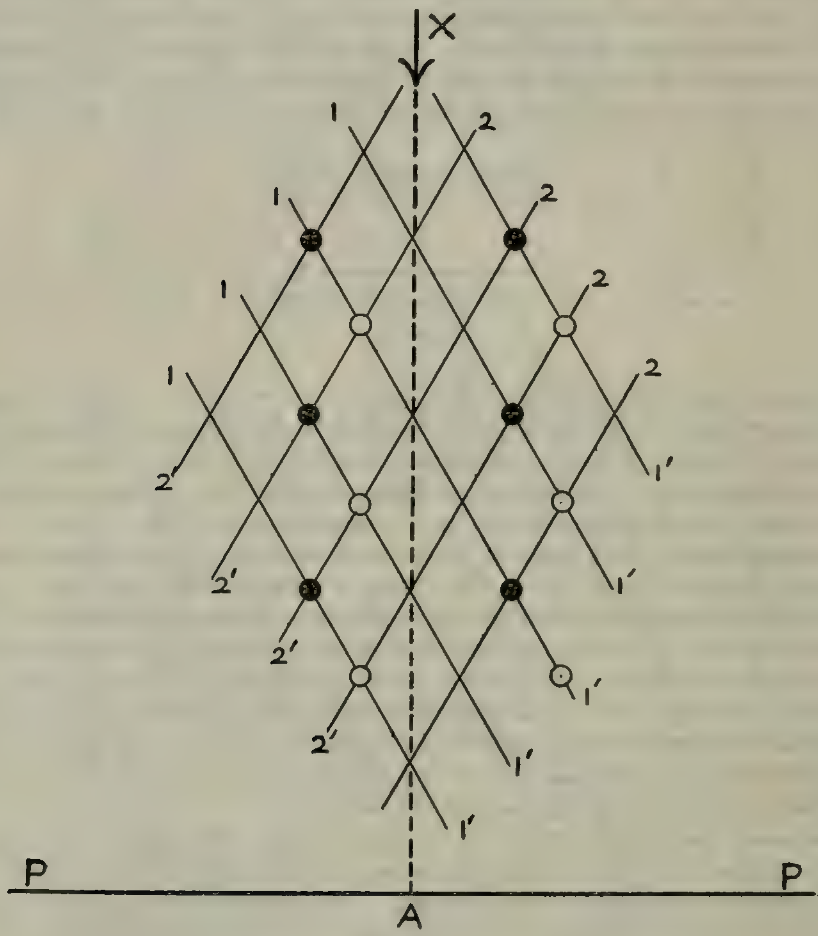


FIG. 9.

alternative the even orders of (100) are relatively greater than the odd, (110) spectra are normal, and the second order of the (111) is abnormally small. It is easy to distinguish between the two cases. The latter is adopted by zinc blende. Each atom has the symmetry of Class 31, to which the crystal belongs, there being only one atom of each in the unit cell.

In this case we are successful from X-ray measurements alone in determining the mode of arrangement of the crystal, although the crystal is polar and the X-rays cannot detect polarity directly. We have been able to determine the structure completely, and the polarity then appears.

When the determination of structure cannot be carried far enough, the X-rays may fail to decide between the presence and absence of polarity. For example, resorcinol is an orthorhombic hemihedral crystal: this is known by its external form. The X-rays show that, this being so, its internal arrangement must be that of M^xM^y or C_{2v}^{10} in fig. 7. If we had no help from the study of external form, or from any other source, we should not be able to decide between C_{2v}^{10} and the more symmetrical mode known as Q_h^{12}: the symmetry of the latter is obtained by adding a centre of symmetry to the elements of symmetry possessed by C_{2v}^{10}: that is to say, by removing the polarity of the crystal. As a matter of fact, the external form of resorcinol clearly shows polarity: or, if we could be sure that the molecule had no symmetry, we could infer that the crystal was unsymmetrical about the *xy* plane, there being only four molecules in the cell and all these being wanted to give the symmetry observed by X-rays. Thus there are cases where the X-rays cannot decide between two modes, one of which can be derived from the other by the addition of a centre of symmetry. As, however, the existence of a centre of symmetry can generally be decided by other means—for example, by such means as I have described above in the case of zinc blende or of resorcinol—this incapacity of the X-ray method is of no great consequence.

The addition of a centre of symmetry moves a structure from one class to another—Class 1 to Class 2, Class 31 to Class 32. Consequently, the X-ray methods are by themselves sometimes in doubt between two modes in different classes when they are rarely in doubt as to the mode within a class. It will readily be understood that the doubt as to class may be of far less importance than the doubt as to mode; though hitherto the former kind of difference has been given all the attention because it has been the only kind that could be observed. A very slight relative movement of the atoms would be sufficient to reduce the symmetry of the crystal from one class to another: but the change from one mode to another within the same class would mean a complete rearrangement of the molecules.

There are two cases in which the X-rays cannot distinguish between two modes in the same class. These are Q^8 and Q^9 in the enantiomorphous class of the orthorhombic system, and T^3 and T^5 in the tetartohedral class of the cubic system. The ambiguity disappears, however, if there are only two molecules in the unit cell, when the former alternative is alone permissible in each case: it would disappear also in any case in which the structure could be determined completely by any other means.

It has been known for many years, thanks to the work of Fedorow, Schonflies and Barlow, that the 230 modes of arrangement represent all the possible forms of internal crystal structure. In each mode of arrangement there is a relative disposition of planes, axes and centre of symmetry, which is characteristic of the mode, and the mode may be described in terms of these symmetries. This was the language used in the original work on the subject, and the term 'space group' was used, instead of the term 'mode of arrangement,' in reference to the particular group of symmetry planes, axes and centre in space. When the subject is approached from the point of view of the X-ray worker, the language of the mode of arrangement has its special conveniences. A list of the 230 modes, and of the X-ray tests for each mode, has recently been published in the Transactions of the Royal Society by Astbury and Yardley. Lists of the same 230 space

groups have already been published in different terms by writers on crystallography: recently a list by Wyckoff has been published by the Carnegie Institution of Washington, in which each space group is expressed in terms of the co-ordinates of the arrangement of points required to give each space group its special characteristics.

It may be of interest to look at these matters from a somewhat different point of view, which takes in the question of the permanence of the chemist's molecule when built into the solid structure.

In every crystal the unit can be divided into a certain number of parts, each of which has no symmetry of its own, but may be made to coincide with any other part by some combination of reflections, rotations and shifts. The number is always either one, two, three, four, six, eight, twelve, twenty-four, or forty-eight. The division into 230 modes of arrangement refers to the arrangements of these parts. In the case of a crystal of the rock-salt type both the positive and negative portions of the cell can be so divided. Very often the part in question is the chemical molecule. For example, the cell of the monoclinic prismatic class can be divided into four such parts. The X-ray measurements show that the unit cell of benzoic acid which belongs to this class contains four molecules. Also they detect the existence of the four parts, and determine the mode of their arrangement. It is natural to make the assumption that each part is a molecule. This, it may be noted, involves the existence of right- and left-handed molecules, as built into the crystal.

Sometimes the division into parts involves the division of the molecule. The molecule then consists of two or three or more parts, and therefore possesses a corresponding symmetry. For example, the naphthalene molecule in the naphthalene crystal contains two parts, and has a centre of symmetry. The molecule of FeS_2 in the crystal of iron pyrites consists of six parts, and has a centre of symmetry and a trigonal axis. Each of the two atoms in the rock-salt cell, sodium and chlorine, has—that is to say, its relations to its neighbours have—forty-eight parts, and therefore the full symmetry of the crystal.

Much more rarely a part consists of more than one chemical molecule. So far a few instances have been met with. The 'part' in the crystal cell of sulphur certainly contains two, perhaps more, atoms. Miss Yardley finds that the 'part' in the fumaric acid crystal contains three, perhaps six, of the molecules as ordinarily defined $(COOH.CH:)_2$. In the cell of α-naphthylamin at least three molecules go to a part. The part has no symmetry, so that the molecules that compose it differ from each other in some way. These are really examples of polymerisation in the crystal.

Is the grouping of the atoms in the molecule as displayed in chemical reactions maintained without change? When the first results of the new methods were published, with their determinations of diamond and rock-salt structure, there was some unnecessary alarm as to the apparent disappearance of the molecule. If there had been anything to suggest a complete disruption of all the alliances in the molecule, which had been so long and so successfully studied by the chemists, the alarm would have been justified. Atomic bonds would have been annoyingly variable and dependent on conditions, and we should have been put back to the starting-point in the investigation of the solid. This condition of things appears, fortunately, to have no existence. The conclusions of chemistry are carried

into the solid, with only such modifications as might reasonably be expected. Our new science is in full and close alliance with chemical science already established: it is in fact a constant and delightful experience to find some direct confirmation or illustration of an inference already drawn from other sources. So far as experience has to tell us, the chemical molecule generally takes its place as such in the crystal structure with little change.

To sum up, we are now able to replace the rough division into thirty-two by the finer division into 230. This is advancing a whole stage towards the final solution of the structure problem. We carry the analysis right up to the limits which can be foreseen by the mathematical investigation of the geometry of space. We require only a sufficient number of X-ray measurements: if these can be obtained, the crystal then—with certain additional information as to polarity—can be assigned to its particular mode or space group, with one or two exceptions as already noted. It may be that the structure of the crystal is so simple that having got so far the full solution is already in sight. In the vast majority of cases this is not so; we have only come to the end of the second stage of the work.

The first stage was complete when we had found the dimensions of the crystal unit cell: the second is completed when we know which of the 230 possible arrangements of molecules, or, in other words, space groups, the crystal structure follows.

If the structure of the crystal is not yet obvious—and in the great majority of cases this is far from being the case—we enter on a third stage, in which the mode of procedure is less stereotyped and more difficult, perhaps all the more interesting. We have now to find, if we can, the arrangement of the atoms within the cell, to which task the knowledge already gained is an indispensable though, it may be, a quite insufficient contribution.

As I have said already, the X-rays do not tell us directly the relative positions of the atoms within the unit cell. They have, however, much to tell us as to the relative intensities of the different orders of reflection by each plane, and these must depend on the atomic arrangements. It is to be admitted, however, that we are as yet unskilled in the interpretation of this evidence. We do not completely understand how varying conditions affect intensities of reflection, though we have learnt a great deal through the work of W. L. Bragg, Darwin, Compton, and others. And, of course, when the cell contains many molecules, their positions being as yet unknown and their separate contributions to the intensities in any case doubtful, the observations of intensity are very difficult to make use of, though they can be accurately measured. We can only avail ourselves of such bold indications as that a very strong reflection implies the location of many atom centres on or near the plane in question, particularly if there are higher orders: or we may find ourselves able to show that an especially strong second or third or other order implies the adoption of some particular alternative arrangement. A very interesting example of a general influence of form upon intensity is to be found in the reflections from the fatty acid layers which have been investigated by Muller and Shearer. The first, third and other odd orders are much more intense than the second, fourth and other even orders. A simple explanation is found in the fact that these long chains face opposite ways alternately, and that the number of scattering centres is distributed fairly evenly along their length. At the ends, however, the uniformity of distribution is interrupted; at one end,

probably the carboxyl end, there is an excess per unit length; at the other, the methyl end, a deficiency. Thus we may say that the effect on an odd order of the spectrum due to a single layer, the thickness of a layer being twice the length of a molecule, contains a factor :—

$$A \sin(\omega t-\alpha)-B \sin(\omega t-\alpha-\overline{2n+1}\pi)=(A+B) \sin(\omega t-\alpha).$$

The factor for an even order is :—

$$(A-B) \sin(\omega t-\alpha).$$

If at both ends there had been an excess of scattering centres, we should have found the even orders stronger than the odd: the effect we find, for example, in the (111) planes of rock-salt. In the case of the simpler inorganic crystals like rock-salt, diamond, and so on, intensity observations are conclusive as to the structure: in the case of iron pyrites or calcite they are very nearly so. But in the case of quartz, where the cell contains nine atoms, still more in the case of an organic compound, they do not carry us very far. We hope that greater experience will give us in the future the power of using them to better advantage.

In what other direction then shall we look for additional means of approaching more nearly to the final solution of the problem of structure?

The answer to this question will take account of all the store of physical and chemical knowledge which we already possess. Having solved, wholly or in great part, the structure of some of the simpler crystals, and being able to proceed in all cases, even of the most complicated crystals, to the determination of the number of molecules in the cell, and of their mode of arrangement, we must try to correlate what we have found with the properties of the crystal. By that means we shall become gradually more certain of the general connection between the structure and its physical and chemical properties; we shall become able to settle further structural details in various cases, and so, by alternate and mutually supporting advances, we may hope to reach our goal.

Let us consider what is being done in this direction. First of all there is the question of the distribution of the atoms in space. Given so many atoms, to be packed into a cell of known dimensions, what information have we as to the space that each must occupy? The answer to the question cannot be simple, because we may not expect that the atoms are always to be treated as spheres, still less as spheres of constant radius. It is as generally difficult to state the distance between one atom and another as to state the distance between a table and a chair. Nevertheless, the atom-radius is a useful conception, especially when its dependence on the nature of combination is taken into account. The question has been considered by W. L. Bragg, Wyckoff, Davey, and others, and it appears that an atom does make a definite contribution to the distance between its centre—when it can be assumed to have a centre—and the centre of a neighbour, so long as the nature of the bond remains the same. This is a valuable contribution to the study of structure. It is proved by the examination of simple structures like those of the alkaline halides, and we may assume its reliability in our attempt on more complicated problems. And, of course, it is interesting from the point of view of atomic structure itself, and atomic linkages.

The radius seems to depend on the tightness of the bond as in bismuth

or in graphite, where there are two kinds of bonding, and the plane of cleavage cuts across all the longer distances from centre to centre. In calcium fluoride the centres of calcium atoms are closer together than they are in the metal itself in spite of the interposition of the fluorine atoms; and in calcium oxide they are still closer. The change in the type of the bonding has altered the value of the radius.

There is also the very interesting but still more unsettled question of the mutual orientation of the bonds between an atom and its neighbours. It is, of course, the carbon atom which is the occasion of this problem in its most pressing form. In the diamond the exactly tetrahedral arrangement of bonds is associated with great rigidity, which implies great stiffness of orientation. The analysis of the structure of graphite has lately been carried by Bernal to a stage very near completion, but the only point in any doubt is unfortunately the very one as to which certainty would be welcome. Has the great weakening of one bond interfered with the relative orientation of the other three? Debye thought that the structure was trigonal, and that the atoms were arranged in layers which were like the layers of diamond, except that they were flattened out without a sideways extension of the network. This would involve a closer approach of carbon atom centres from 1.54 A.U. to 1.45 A.U.; against which no obvious objection can be offered, but it would be interesting to know how it happened. Hull believed the structure to be hexagonal, and that the layers remained as in the diamond. Bernal, having found some good graphite crystals to which the single crystal methods could be applied, finds that Hull is correct as to the hexagonal structure, but inclines to the belief that the layer is flattened. In the latter case, we must suppose that the carbon atom has three very strong bonds almost coplanar with the carbon, and one weak bond at right angles to this plane.

The question arises in another form in the investigations of the long carbon chains by Piper and others, and especially by Muller and Shearer. If the chains are formed by the linking of carbon atoms together in such a way that the junctions of one atom to its two carbon neighbours are inclined to one another at the tetrahedral angle of 109°28′, as in diamond, then there are three possible forms of chain. In one of them, each two carbon atoms imply an increase of 2.00 A.U. in the length of the chain, and, in a second, an increase of 2.44 A.U. In these two cases the carbon atoms of a chain can lie in a plane. With one exception, all the cases examined show one or other of these two rates of increase. The third form of chain is a spiral, for which the growth of each single atom added is 1.12. In one case this rate of increase is found to hold: it is that in which the chain contains a benzene ring. This agreement between calculation and experiment shows with some force that the relative orientation of the bonds is maintained. Even when two or four hydrogens are stripped from the chain at various points, so as to leave a double or triple bond between consecutive carbon atoms, to adopt the ordinary chemical language and theory, no measurable change is found in the length of the chain. This does not mean that there is no change in the distance between neighbours: such a change would be small and might escape detection. But it does mean that there is no great change in the general straightness of the chain, such as might be expected from any large change in the mutual orientation of the bonds between the carbon atom and its neighbours.

In calcite the three oxygens which surround a carbon atom must lie in one plane. It is supposed, however, that in this case the bonds are electrostatic : the carbon atom has lost its four valency electrons, and with them its powers of tetrahedral orientation.

Now if we can discover the extent to which an orientation is maintained under different conditions we are provided with one more guiding principle in our attempt to discover the structure of the crystal which contains carbon atoms. And, of course, the organic compounds centre round the carbon atom and its tetrahedral structure.

The question of orientation in respect to other atoms is more obscure, but it is clearly one of importance. There must be some reason why ice has such an open structure, and here the oxygen atom is largely concerned. In the ruby the oxygen atom has no plane of symmetry in relation to its neighbours. In organic substances the great emptiness of the structure implies that atoms are attached to one another at points which have definite positions on the surfaces of the atoms and are limited in number. And, generally speaking, the consideration of organic crystal structure is against any idea that atoms and molecules are to be treated as spheres surrounded by uniform fields of electric force, except in certain cases where by loss or gain of electrons an atom has been reduced to the outer form of one of the rare gases. They must have highly irregular fields, having forms which more or less resist any change. The weak bonds which hold molecule to molecule in the organic substance are not due to electron sharing as in diamond, or to ionisation as in rock-salt, but to an intermingling of stray fields belonging to definite positions on the surfaces of the molecules.

Our attempt to discover the effect of orientation is part of a general attempt to discover the field of force of the atom, which is naturally a very difficult matter. But if we can learn only a few rules, even empirical rules, we are so much the further on our way.

Yet another obvious and most important source from which help may be obtained is to be found in chemistry itself. Although the chemist has had no means until now of measuring distances and angles, he has been able to build up a wonderful edifice of position chemistry. An atom A of a molecule is certainly linked, it may be to B, and not to C ; or again, of a number of atoms of the same nature and contained in the same molecule, so many must be alike, and so many may be different.

The chemist has, for example, come to the conclusion that the naphthalene molecule is a double benzene ring, and the anthracene a triple benzene ring. The X-ray observations show that one of the sides of the unit cell of the latter crystal is longer by 2.5 A.U. than the corresponding side of the other, all other dimensions of the two cells being very nearly the same. The width of the hexagonal ring in the diamond is 2.5 A.U., so that on the one hand the chemical evidence suggests that the length of the molecule is parallel to that edge of the two cells which shows differing values, and on the other the X-ray conclusions give material support to the chemical view. Let us take another example from basic beryllium acetate, $Be_4O(C_2H_3O_2)_6$. The substance is remarkable for the ease with which it sublimes into a vapour consisting of whole molecules, from which we may infer that the molecule does not suffer much change in the process. The relative positions and mutual alliances of the atoms are nearly the same when the molecule is free as when it is built into the solid. From the

X-ray evidence we learn that the molecule has four intersecting trigonal axes. We must place the unique oxygen at the centre of a regular tetrahedron, and the four beryllium atoms at its corners. Each of the six acetate groups must be associated with one of the tetrahedron edges, and in such a way that the four trigonal axes are maintained. This necessitates, as crystallographic theory shows, the existence of a dyad axis through the middle points of each pair of opposite edges of the tetrahedron. The $C_2H_3O_2$ groups must be added so as not to interfere with the existence of these axes. If they are placed correctly for the trigonal axes, each of them has a dyad axis of the kind mentioned. All this agrees with the chemical evidence as partly stated in the formula, which implies :—

1. That there is one oxygen differently situated to the rest.
2. That the four beryllium atoms are all alike.
3. That the acetate groups are all alike.

Further, chemists would say that the carbon atoms are not alike ; in that case, they must both lie on the dyad axis, since if they did not they would necessarily be symmetrically placed with respect to that axis and would be equivalent. On the other hand, the oxygen atoms in the acetate group cannot lie on the axis if, as is probable, they are equivalent to one another. They must be placed symmetrically with respect to the dyad axis. As to the hydrogens, we must assume either that they do not count, which is not at all unlikely, or that they are not all alike. It is impossible to place eighteen hydrogen atoms so that the group has four intersecting trigonal axes and that every hydrogen is like every other. The molecule has no plane of symmetry, the fault lying with the oxygens. It could not be due to the hydrogens because there are marked differences in the intensities of reflection of pairs of planes, which differences would not exist if there were planes of symmetry, and would be small if due to dissymmetry in the positions of hydrogens only. It is by reasoning along such lines as these that X-ray evidence and chemical evidence can help each other. Many other instances might be given ; indeed, no complex crystal can be studied with success without calling in the assistance of chemical arguments.

A fourth example of the connection between arrangement and properties is to be found in the recent work by W. L. Bragg on the indices of refraction of crystals. It has been found possible to calculate the indices of refraction of calcite, given the dielectric capacities of calcium, carbon and oxygen atoms separately. The difference between the two principal refraction indices is almost entirely due to a difference between the dielectric capacities of a set of three oxygen atoms, at equal distances from one another, when placed :—

1. So that the plane in which they lie contains the direction of the field.
2. So that this plane is perpendicular to the field.

If we are able to calculate the refractive indices on these data, then it must be possible to find conditions governing the arrangement of the atoms, when we know the composition of the crystal and its refractive indices. For instance, the near equality of the refractive indices of potassium sulphate implies that the dielectric capacity of the SO_4 group is much the same in all directions, and this is in agreement with the hypothesis that the

oxygen atoms are grouped in some sort of tetrahedral fashion about the sulphur atom.

There are still other connections between structure and properties which we begin to understand, and can use in proportion to our understanding. The cleavage plane, and the occurrence of certain faces in preference to others are connected with the nature of the bonds and the size of the spacings. We are not surprised to find that in bismuth, or graphite or naphthalene, the cleavage plane cuts across the ties which we should expect to be the weakest of those that bind the molecules together; or again, that natural faces follow the planes that are richest in atoms or molecules and may be assumed to contain relatively large numbers of linkages. In naphthalene the cleavage plane passes between the ends of the molecules, where the β hydrogens are, and where there is a deficiency in the number of scattering centres, as the X-rays indicate by the strengths of several orders of the (001) reflection. The other faces found on the crystal cut across the ties at the positions of the α hydrogens.

There are many other connections between the structure and other properties of a substance, such as dielectric capacity, rigidity, and compressibility, conductivity both thermal and electric, magnetic constants. In fact, the only properties of solid bodies which are not directly and obviously related to crystal structure are those, few in number, that depend on atomic characteristics alone, such as weight; and the absorption coefficients for α, β, γ and X rays, all the rays which involve high quantum energies. With few exceptions every aspect of the behaviour of a solid substance depends on the mode of arrangement of its atoms and molecules. We have, therefore, an immense field of research before us, into which the X-ray methods have provided an unexpected and welcome entrance.

They tell us directly, as I have said, the number of molecules in the crystal unit cell, and the mode of their arrangement with such determination of lengths and angles as are required to define the mode of arrangement in full. They leave us then to ally our new knowledge to all that we possess already as to the physical and chemical properties of substances. By this comparison we hope in the end to determine the position of every atom, and explain its influence through its nature and position upon the properties of the substance. It is the chemistry of the solid that comes into view, richer in its variety even than the chemistry we have studied for the past century, and possessing an importance which is obvious to us all. Every side of scientific activity takes part in this advance, for all sciences are concerned with the behaviour of matter.

SECTION B.—CHEMISTRY.

CHEMISTRY AND THE STATE.

ADDRESS BY

SIR ROBERT ROBERTSON, K.B.E., F.R.S.,

PRESIDENT OF THE SECTION.

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Introduction.

It should be premised that in this account of the relationship of the State to chemistry in Great Britain, an attempt has been made to limit it to a description of the more or less direct assistance given by that science to various departments as they came into being or took form. Only in recent years, and as a result of the war, has there been a direct recognition of a corresponding obligation on the other side.

It is obvious that it is to the universities, and, as was the case to a greater extent in the past, to private workers, that the great advances made by British chemists are due. Departmental requirements have, of course, reaped the advantage of these advances, but examples of important contributions to chemical knowledge emanating from the departments themselves are not lacking. The collected story of their connection with the activities of the State may be worth reciting, if it should show the development of its appeal to chemistry, and illustrate the gradual breakdown of the view held by the chief of the tribunal before which Lavoisier came, that 'the State has no need for chemists.'

We will find that their employment in an official capacity was in the first instance in connection with the State's pressing necessities, such as its defence, the regulation of its currency, and the collection of its revenue, all of them subjects warranting the maintenance of equipment and staff.

As the need for safeguarding the nation's health, well-being, and the quality of its food supply became recognised, legislation followed, frequently

based on the work of Commissions on which sat distinguished chemists of the day, and it became necessary to set up a State chemical department to assist in carrying this into effect.

For some time the science of chemistry had received a limited and vicarious assistance from State grants to the late Science and Art Department and to the universities, but it was reserved for the war to establish definitely and finally the position that the whole future existence of a State might and probably would depend on the existence of a flourishing and efficient chemical industry. This resulted in the definite steps of assisting the application of science to industry, and providing direct encouragement for workers in the purely academic field.

It is proposed, therefore, to sketch the development of the main chemical activities of the State, and to review the conditions in Great Britain in the hope that it may be of use generally to define the present position, and perhaps of interest to this Dominion in the present stage of its chemical development.

Defence.—Explosives.

It would appear that the importation of the technical process from abroad is no new thing, for it is stated that in 1314 gunpowder and guns were being imported into England from Ghent. Not only the material but the executant also appears to have been imported in the person of a John Crab, a Fleming, who took service with the English and supervised the guns and munitions used at Crécy. By 1338, cannon were mounted on board English ships of war, and in 1346 gunpowder was being supplied to the King. Although the manufacture of gunpowder is mainly a mechanical operation, variations in the composition which must have involved chemical experiment are recorded in such works as the 'Fire Work Books' of that interesting class, the Master Gunners. In England, a Master of the Ordnance in 1447 is stated to have made 20 tons of gunpowder. This manufacture, however, early became stabilised, and the proportions of the composition underwent little change until the middle of the nineteenth century, when it was modified, but as freedom from smoke began to be demanded a new propellent of a type that could be produced only by chemists was evolved.

It is of interest that Faraday was employed by the War Office as Lecturer at the Royal Military Academy from 1829 to 1853, and on appointment took as his assistant James Marsh, whose name, associated with the process for determining arsenic, is so well known to chemists. Marsh received the gold medal of the Society of Arts for this work, and a silver medal from the Board of Ordnance for his discovery of the quill percussion tube for cannon, and further he devised some of the earlier types of time-fuse. Abel succeeded Faraday at the Academy and began his long career of activity as scientific adviser to the War Office, becoming War Department Chemist in 1854.

It is necessary to mention some of the important advances made by Abel and his staff, including Kellner and Deering. By pulping guncotton, he rendered it safe to handle and store; his researches on the properties of guncotton laid the foundation of later work on its stability and explosive properties; and his research (with Noble) on the behaviour of gunpowder when fired is an example of a thorough investigation. Abel was consulted

also on subjects other than explosives, and in his laboratory were conducted experiments which led to the adoption in 1879 of the present close-test apparatus for testing the inflammability of oils, experiments on steels and the effect of foreign materials in them, experiments on dangerous dusts and on the cause of accidents in coal mines.

The work of Abel in rescuing nitrocellulose from the position of an erratic substance, liable to decompose and explode on storage, led to its use as a reliable explosive, not only for military purposes, but also in commercial compositions, such as sporting powders and blasting explosives.

When it became necessary to devise a smokeless propellent for the British Service, the chemical work was in the hands of Abel with his assistant Kellner, Dewar, and Dupré, and in 1890 this resulted in the recommendation for the adoption of cordite.

It now became necessary to extend the only chemical manufacture carried on at the Royal Gunpowder Factory, that of guncotton, by adding the manufacture of nitroglycerine, the technical handling of cordite, and plant for treating acids, and accordingly in 1891 a chemical manager of this section with a staff of chemists was appointed.

The chemical work carried out by the British Government for defence, both as to its immediate object and as to its reaction on the explosives industry of the country, is worth review. In such a review the position before the war may first be described. Propellent manufacture was seriously undertaken, the small quantity of high explosive used at this time being mostly obtained from private manufacturers. Guncotton, as has been stated, had been manufactured by Abel in a fairly stable form, and this explosive was chosen for the Service propellent cordite, together with nitroglycerine and mineral jelly, the mixture being gelatinised by acetone, so that in a plastic condition it might be squirted into the cords which give it its name. A close study was devoted to this manufacture in all its aspects; the processes of manufacture were greatly improved, and the dangers reduced.

The Royal Gunpowder Factory took its place as a model of an explosives factory, and afforded an example of what could be done by a State department in conducting a scientific manufacture with regard to improved technique, economy, and efficiency. Thus the method of nitration to produce guncotton was greatly improved in safety, freedom from fumes, and ultimate stability of the product, by the adoption of the process of downward displacement of the waste acids from the nitrated product by a layer of water; for nitroglycerine a displacement process by which the layer of that liquid, separating on the surface of the waste acids, was caused to overflow from the top of the vessel by introducing waste acid from a previous charge at the bottom, led to an increased safety and yield, and saved height in the erection of a factory; the chemistry of the process of guncotton boiling was worked out and placed on a scientific foundation; and acetone, which in the process of drying the cordite had been allowed to escape into the air, was recovered from the drying stoves and saved for further use. These advances in manufacturing method were taken up by other manufacturers, both in the United Kingdom and abroad.

In the technique of the manufacture of propellent explosives before the war this country then had advanced to a high pitch of efficiency, so

that when the demand came for enormously increased quantities of propellents, new factories, such as that of Gretna, took up the manufacture on lines already well established.

Safety in manufacture had also been closely studied, and precautions introduced that commended themselves to private firms. It may be said in this connection that the application of the Explosives Act of 1875 by the Home Office Inspectors of Explosives has been of much benefit to the explosives trade in reducing casualties. Perhaps in no other country are precautions taken to such an extent as in Great Britain, so that to visitors from abroad they sometimes appear unnecessary and vexatious, but experience has shown that the policy is sound, especially as it brings into all sections of the work an atmosphere of carefulness and responsibility, with an eventual gain in health of the workmen and freedom from accidents.

Research on explosives before the war was carried out at the Royal Gunpowder Factory and at the Research Department, Woolwich. At the former establishment, the chemistry of the products manufactured was investigated, especially with regard to the mode of decomposition of guncotton, of nitroglycerine, and of cordite; their respective rates of decomposition at different temperatures were determined, a subject bearing on their behaviour on storage. Knowledge of this kind is essential in a Service such as ours, on account of the extremes of temperature from tropical to frigid to which explosives may be subjected in stations throughout the Empire.

At Woolwich an experimental establishment had been set up on the instigation of Lord Haldane to deal with explosives and metals used in gunnery. Here the study of the chemical and explosive properties of all types of explosives was undertaken and methods were developed for determining their stability and sensitiveness. This knowledge found application in laying down criteria for the choice of explosives for use in a Service whose demands are exigent on account of the drastic conditions above mentioned, affecting both storage and the design of mechanism containing explosives. So far as the subject-matter is not considered to be confidential, this work has been published in scientific journals, so that it is available in connection with the study of the theory of explosive substances.

A new phase was entered with the declaration of war, and ultimately all chemical help was mobilised for the defence of the realm. A nucleus existed at Woolwich, where the small staff of eleven chemists had been occupied in the study of explosives and their application. In two directions this experience proved of importance, for it enabled immediate answers to be given to questions which would otherwise have necessitated protracted storage trials, and it afforded the staff the training necessary to qualify them to meet the fresh demands that became urgent on the outbreak of hostilities.

After the beginning of the war the increase of work imperatively called for a larger staff, and more chemists were appointed, until at the beginning of 1917, the home supply being exhausted, permission was obtained to withdraw from France members of the Special Brigade, R.E., of whom more than thirty were transferred to the Department. Finally, the chemical staff numbered 107 chemists and physicists distributed in an organisation which had been gradually evolved, comprising sections for

dealing with different classes of work, such as organic chemistry, physical chemistry, analytical and general chemistry, physical investigation, calorimetry, stability, pyrotechny, applications of high explosives, fuse design, and records.

The manufacture of high explosives had not previously been undertaken by Government, and the known processes for making trinitrotoluene, which was early chosen as a Service high explosive, were unsatisfactory. One of the first subjects, therefore, taken up after the outbreak of war was the provision of an efficient and rapid process for the manufacture of trinitrotoluene, especially without the use of fuming sulphuric acid (oleum). From the results of a large series of nitrations in the laboratory, a process was evolved characterised by several novel features, and this was put to the proof on the semi-industrial scale of a quarter-ton, a plant being designed and erected in the Research Department, Woolwich, for nitration, including appropriate arrangements for the mixing and concentration of acids. This small plant substantiated in a remarkable way the process evolved from the laboratory work, and from the start turned out trinitrotoluene of good quality and yield. The process found immediate application in the large Government factories that were designed and erected by Mr. Quinan and also in numerous private works built at this time. The small-scale plant mentioned was used also for the purpose of training chemists, who proceeded to operate chemical plant in Government and private factories.

A study of trinitrotoluene in all its aspects was undertaken, and much attention devoted to its chemistry, the proportions in which the isomers occur in the crude product being determined by thermal analysis, and investigations were made on their interactions, stability, sensitiveness, heat values, and explosive properties. Most of the scientific results of this work have since been published.

When it became evident, as it soon did to Lord Moulton, that the supply of high explosives in use, lyddite and trinitrotoluene, would not suffice, the Research Department put forward mixtures of ammonium nitrate and trinitrotoluene, the amatols, as a result of a study of their properties and of their effects in shell-bursting trials. Gun trials confirmed these trials at rest, and the adoption of amatol as a high explosive quickly followed. Various methods of filling these mixtures into shell were at this time worked out, and many of them were applied on the very largest scale.

It was found that 80/20 amatol (80 parts of ammonium nitrate to 20 of trinitrotoluene) was less easy to bring to detonation than lyddite or trinitrotoluene itself, and it required special arrangements in the train of initiation of detonation. These were successfully devised, and good and trustworthy detonation of our shell was secured. Ultimately, amatol became practically the only explosive for land and aerial warfare, and justified the early estimate of its properties and capabilities. It is economical in that it makes use of a cheap ingredient, and has explosive properties that render it very suitable for the purposes for which it is used. In 1917 the production was at the rate of about 4,000 tons a week.

The Department continued the study of amatol, especially with regard to its chemical stability and compatibility with the various materials with which it came into contact. Certain impurities in ammonium nitrate were discovered to be objectionable, and investigation of these led to an

improvement in the purity of the ammonium nitrate supplied. The manufacture of amatol and the modes of filling it into shell occupied the attention of a large staff of chemists attached to the factories, and an increase in knowledge of its chemical and physical properties led to improved methods of handling it.

The Service propellent cordite required for gelatinisation in the course of its manufacture the solvent acetone, of which the supply ran short when the programme for propellents began to exceed all previous calculations. To meet this situation, cordite of the existing type was retained for Naval Service, but for Land Service a modification was introduced under the name of cordite R.D.B. (Research Department powder 'B'). This propellent could be made without any alteration in the plant required for the manufacture of cordite. Instead of acetone the solvent employed was ether-alcohol, and instead of guncotton a lower nitrate of cellulose was used. The great factory at Gretna, also built by Mr. Quinan, manufactured cordite R.D.B. exclusively, and this soon became the only propellent made in this country for the Land Service. It was produced both by Government and by private firms in enormous quantities. The alcohol was made in the country from grain, and ether was produced from it, so that dependence on sea-borne solvent was reduced. It was this need for alcohol that led to the restrictions imposed on that liquid when used as a beverage.

Numerous problems arose in connection with these manufactures as they developed and in the application of the explosives in the various types of ammunition, and these necessitated the study of the explosives in all their aspects. A large addition to the knowledge already existing was thus acquired on the more theoretical side of the study of explosives, and much of this has been made available by publication.

As the demand on our resources increased, and the necessity grew for investigating every source of supply and possible alternative, it came to pass that nearly every professor of chemistry in the country was mobilised for investigation in this field and in that of chemical warfare, and much valuable work was done by them, both of a research and inspectional nature.

For the manufacture of explosives and the operation of filling them into munitions of various kinds in the existing factories and the new ones which sprang up, a large staff of chemists, amounting to about 1,000, was required, and in this way many chemists whose earlier work lay in quite other directions, such as at the universities or in teaching posts, received an insight into technology and took control of workmen.

During the war itself, instructional work in this subject was not wanting, for current progress in the factories under his control was discussed in a systematic manner by Mr. Quinan with representatives of his staff, a course which led to important improvements. Although most of these war-time plants for the manufacture of explosives have been dismantled, much of the technical experience gained has been saved, and will be found incorporated in a series of memoirs (Technical Records of Explosives Supply) published by H.M. Stationery Office. The information set forth in these volumes is in a form which has a much wider appeal than to the explosives technologist only, and their study is commended to those who take up the subject of chemical technology in any of its aspects.

In addition, factories for the production of substances not in themselves explosive equally required the services of chemists, and many were employed in the production of such substances as methyl alcohol, acetone, and acetic acid.

Instruction in chemistry is provided by the Fighting Services for Naval and Marine cadets at Dartmouth, and for Army cadets at the Royal Military Academy and the Royal Military College, Camberley. For selected officers, both of these Services have a professorial staff for providing systematic courses in theoretical and practical chemistry, with special reference to Service applications, at the Royal Naval College, Greenwich, and at the Artillery (formerly the Ordnance) College, Woolwich.

Defence—Chemical Warfare.

While our well-developed position of the great inorganic chemical manufactures was a source of strength when the demand came during the war for an enormous production of ammonium nitrate, for example, our neglect to foster a great organic chemical industry led to dangerous delays and improvisations. This was apparent from the beginning when several universities had to co-operate to produce a sufficient supply of local anæsthetics, and when presently our lack of dyes, photographic developers and sensitisers revealed our former dependence on foreign supplies. In November 1914 the Royal Society had set up a Committee to assist the Government, and this became an Advisory Committee when, after May of the following year, the gas attack caused the British Government, which up till then had scrupulously refrained from its use, to retaliate with that weapon. Special companies were created of chemists whose work often had little of a chemical aspect, but many of these men, in twelve to eighteen months, had to be withdrawn for research and control of plant. Chemical advisers were appointed to the armies and for liaison purposes, a central laboratory for rapid identification was established in France, and co-operation was effected with the physiologists. At home assistance was afforded to chemical contractors, and the manufacture of respirators to meet needs rapidly becoming more complex was carried out with great vigour and efficiency. The increasing importance of gas warfare led to a proving ground at Porton being acquired, when the research which had been carried out at the Imperial College at South Kensington became centralised there. As the final proof of explosive projectiles is carried out at Shoeburyness, it was now possible on this new proving ground to settle questions relating to the filling and correct performance of chemical shell, thus enabling the Chemical Warfare Designs Committee to recommend ammunition to meet the needs of a situation which was continually developing, until the proportion of chemical shell compared with high-explosive shell was finally a large one.

In the ramifications of this work all the chemical skill in the universities not already applied to explosives was mobilised, since the demand for new designs involved the manufacture of new substances for shell, bombs, and grenades, new smoke and incendiary compositions, and continuous research and experimental work both on the offensive and defensive sides.

In a few cases only was the country capable of expanding its existing manufactures, as in the case of phosphorus and chlorine; it was not equipped for the home production of phosgene, arsenical compounds, or mustard gas. New factories had therefore to be erected and staffs specially trained, in striking contrast to the existence in Germany of standardised plant capable of rapid transference from one purpose to another with little alteration: an example of this was their manufacture of arsenical preparations in the azo-dye sheds.

As a result of an intensive study of absorbent substances, our respirator was never beaten, and it is claimed that, although our output was smaller, the better employment of gas, tactically for surprise, lay with us. Starting late and entering a field entirely new, we were able while there was yet time to protect the soldier, and to make a reply on the offensive side that was rapidly becoming more and more effective.

Not all of the work specially devoted to chemical warfare has been without its effect on peace-time requirements. Thus liquid chlorine, of which very little was made in this country before the war, is now being prepared electrolytically and transported by rail in tank waggons for use in various industries. For the preparation of phosgene, which had been used in Germany in the manufacture of dyes of the triphenylmethane series, better methods were discovered in this country, so that cheaper and purer phosgene is being used here for the first time to prepare the important group of colours known as the Victoria blues. Improved methods are now available for the manufacture of arsenical compounds, such as arsenic trichloride, a substance used for combàting the growth of prickly pear in Australia; and mention may be made of the work of Professor Moureu in France on the stabilisation and concentration of acrolein, as it has led to the production of a substitute for celluloid from that body. In addition, the study of many of the bodies used for chemical warfare has been of value from the aspect of the elucidation of their chemical constitution.

Metallurgy.

When the part played by metals in the history of civilisation is considered, the development of some more durable alloy or some stronger metal appears intimately linked with a distinct advance constituting a new age, often characterised by eponymous association with the metal. As the possession of some superior metal may give ascendency to a people, it is natural that States should show interest in metallurgy, both militarily and to maintain the standard of the medium of exchange. It is thus seen that iron and the precious metals gold and silver have for the most part interested the modern State, the metallurgy of the other metals only more recently coming in for attention on military grounds. Accordingly, we find the armourer and the minter holding important positions in early times.

It must be stated at the outset that the relations in Great Britain between the State and metallurgical science before the war of 1914 to 1918 were for the most part sporadic, the great developments in that science being to a large extent independent of the State. It undoubtedly exerted, however, an influence on the nature and quality of metallurgical products, of which it was a large user for warlike, structural, and shipbuilding

purposes, by specifying the conditions of their acceptance: standards established by the Government, often based on inquiry and experiment, gave confidence to other users and resulted in the improvement of industrial materials.

Although iron-making had flourished intermittently since the Roman occupation, and had reached considerable proportions under Elizabeth, no great contribution to knowledge can be attributed to Great Britain in the progress of metallurgy until the restriction of the cutting down of timber for charcoal towards the end of the sixteenth century forced into consideration the use of coal for smelting, the pioneer work being that of Dud Dudley, who in 1642 cast iron cannon at his foundries for the Royalist troops. It was his experience as an Admiralty official that brought Cort, more than 100 years later, to recognise the inferiority of English wrought iron, and to leave the Service for the purpose of improving existing processes so that his successful wrought iron was accepted towards the end of the eighteenth century for anchors and iron work in the Royal Navy. His invention of the puddling process led to great prosperity in the iron trade.

The need to meet Government requirements became similarly urgent in the case of steel, which in its earlier production as puddled steel so failed in uniformity of composition that as a material of construction it could not be used by the Admiralty, nor permitted by the Board of Trade. Bessemer's great advance of converting molten iron cast into steel by blowing air through it, described in 1856 to this Association, enabled him to propose a material more suitable for guns and projectiles than the cast iron then employed. Bessemer steel came into use for many purposes, and its production increased rapidly, but boiler plates submitted to the Admiralty still showed great variations in carbon content. Meanwhile the rival open-hearth process was steadily developed and established by Siemens. In 1875 the Director of Naval Construction had pointed to the danger due to lack of uniformity of steel made by the converter process, but in 1879 he was able to report the success of the new open-hearth steel. The Government challenge had been taken up by Siemens, who produced a steel to meet all its specifications, so causing its acceptance for Admiralty work, and its admission by the Board of Trade for structural use.

After Thomas and Gilchrist had in 1877 solved the problem of dephosphorising iron by the basic process, the Admiralty instituted an inquiry as to its properties, which led to an official recognition of basic steel, thus greatly enlarging the source of supply through the use of native ores.

Among the men who assisted the Government in these inquiries was Dr. Percy, who placed metallurgy in this country on a scientific basis, while lecturing on that subject at the Royal School of Mines and at the Ordnance College. Abel, appointed War Department Chemist in 1854, gave much attention to the use of iron and steel for military purposes, investigating the question of erosion of guns and throwing new light on the constitution of steel by his isolation of Fe_3C. He did good service in convincing the great ironmasters of the importance of chemistry in their industry. To Roberts-Austen also, Chemist and Assayer to the Mint, many Government inquiries and commissions were indebted for advice on the subjects he had enriched by his researches, such as the physical constants and mechanical properties of metals, the effect of impurities,

the cementation of iron, heat treatment, and many others, including the first 'freezing-point' curve of a series of binary alloys in 1875. It was in consequence of these that his co-operation was invited by the Alloys Research Committee, whose first six reports contained a great deal of his work, covered a wide field, and did much towards the realisation by engineers of the value of microscopical and thermal methods in the study of metals. Later reports to this committee, whose work in 1902 was transferred to the National Physical Laboratory, have maintained their high standard, and have been contributed to by such workers as Carpenter, Hadfield, and Rosenhain.

The last of these reports, the eleventh, embodies work at the National Physical Laboratory from 1914 to 1918, the year when that institution became a part of the Department of Scientific and Industrial Research. It deals with light alloys, the need for which the war has emphasised, especially in connection with aircraft. For this purpose the Laboratory's work has resulted in furnishing alloys of aluminium with zinc and copper, with copper and manganese, and with copper, nickel and magnesium, possessing remarkable and useful properties, such as high tensile strength at ordinary and also at raised temperatures.

Since the war light aluminium alloys continue to be studied at the National Physical Laboratory, which is the Government establishment where metallurgical research is carried out mainly for the advancement of knowledge. Here has been worked out the constitution of many important systems, binary, ternary, and quaternary, in which aluminium is the largest constituent, and the wire models constructed for the ternary alloys have proved of great value in the study of their constitution. Such questions as age-hardening have been investigated and the cause ascertained.

Systems with copper as the dominant metal have been investigated as regards their constitution, as well as the effect on their mechanical and electrical properties of known additions of other substances that may be present as impurities.

But attention is also being given to ferrous alloys for whose investigation specially pure components have to be prepared, in order to eliminate the effect of impurities of which a very small proportion may often have a marked influence on the product, and several equilibrium diagrams with iron as the main component have been worked out. Research on the more physical side includes investigations on the heat evolved during the plastic deformation of a metal, on the effect of heat treatment and composition on the magnetic properties of tungsten steels, on fatigue, and on the physical constants of metals. By the application of X-ray analysis to the crystal structure of metallic systems, Rosenhain has obtained confirmation of his conception of the nature of solid solutions.

The chemical section of the National Physical Laboratory carries out a large amount of work in connection with these researches, the investigation of methods of analysis, and the preparation of standards for the analysis of steel, as well as chemical work of a non-metallurgical nature.

Maintained by the Fighting Services since 1904 to increase the efficiency of the metals used in the manufacture of ordnance and armament, the Metallurgical Branch of the Research Department, Woolwich, increased in numbers, building and equipment during the war, and at present employs about 25 metallurgists. It has been occupied for the most part with steel,

the heat treatment of which in relation to its mechanical properties has been the subject of close study, resulting in improved gun forgings being delivered by the makers. Two main types of steel have been under consideration, those which would give a minimum yield point of about 35 tons per square inch when treated in large masses, and those at about 25 tons. As a result much information has been acquired on the properties and heat treatment of steel containing various proportions of nickel, chromium, molybdenum and vanadium. The study of the elastic properties and of the erosion of gun steel has been of importance to gunnery. The Moore adaptation of the Brinell hardness test, in which a small ball and load are used in a specially designed machine, was originally developed in the Department for testing small-arm cartridge cases, and has since found many other important applications here and elsewhere.

Among other investigations on non-ferrous metals, those on 'season-cracking' of brass and its prevention, and on methods of extrusion, have been productive of useful results, and in connection with the Non-Ferrous Metals Research Association, work is in progress on the casting of brass to produce sounder ingots, on the die-casting of brass and bronze, and on the failure of lead cable sheathing by cracking.

During the war, the use of substitutes, the easing of specifications to increase output with safety, the examination of enemy ammunition, and the tracing of causes of failure and discovery of remedies provided a large field for investigation.

The other aspect of metallurgy of special interest to the State, that of minting, has a long history; from early times the need for a high and uniform standard of coinage, and the crime of debasing it, have been recognised. The difficulties that confronted the early assayers, without methods of quantitative analysis and with no fine balances, are apparent from the description of their methods, but it may perhaps be held that these needs as they became borne in on the early assayers and their frequent collaborators the alchemists, led the way to the appeal to weighing in chemical work.

As early as 928 A.D. laws were proclaimed by King Athelstan appointing 'mynteres' whose products were scrutinised at the trial of the pyx; later, in 1180, supervisors of the coin manufactured by 'moneyers' were appointed.

An official mention occurs in the reign of Edward I. of a Guild of Goldsmiths in London, which had, however, existed since 1180, in an Act providing for the assay of silver vessels by the Wardens of that craft. The earlier writings on the subject of assaying are those of Germans, of whom Queen Elizabeth brought over a number to introduce their methods and assist in the development of the resources of the country.

The course of testing seems to have been originally by means of the touchstone, supplemented much later by observing the effects of acid on the trace left by drawing the metal over the stone, the method of determination of density, the cupellation method, officially recognised by Henry II., and finally the wet method of analysis.

To safeguard the fineness of the coinage a King's Assayer was appointed in 1222, a Master of the Mint manufacturing the coin under contract, and a Warden acting on behalf of the King. A Commission, having toured the Continental mints, reported in 1870 in favour of the present organisation of the Chancellor of the Exchequer being Master of the Mint in virtue

of his office, a Deputy-Master being responsible for the administration, while the valuation of bullion and questions of assay are the duties of the Chemist and Assayer.

Many of the Mint officials have contributed largely to metallurgical knowledge. One of them, William Humphrey, in 1565 received the first patent for making brass, and a later one, Sir John Brattle, communicated work to the Royal Society shortly after its foundation on the oxidation of lead. Sir Isaac Newton when Warden is said to have himself conducted experiments on the composition of foreign coins. The melting-points of metals were studied in conjunction with Wedgwood by Alchorne, who was appointed Assay Master in 1789. From 1851 to 1870 several distinguished men of science, such as Hofmann, Graham (who in 1866 published a work on the effect of the occlusion of gases in metals), Miller, and Stenhouse, were officials of the Mint; but in 1870 it was considered preferable to conduct the chemical operations of assaying within the Mint itself, and Roberts-Austen, to whose pioneering work in metallurgy allusion has been made, was appointed. To his successor, Kirke Rose, are due many advances in knowledge of the precious metals. Thus, researches at the Mint have been directed to the investigation of metallic systems of gold with silver and other metals, the means of avoiding brittleness in gold coins, the electrolytic refining of gold, the mechanism of annealing of metals, the surface tension of solid and molten metals, as well as to improvements in the technique of the methods of assay.

Revenue.

In reviewing the influence of our science in its application to Revenue questions, it is convenient to consider historically the substances on which the State has levied duties.

In the older tariffs, fixed charges were levied on goods considered as a whole, but a time arrived when the chemist was called in; it then became possible to make an assessment on the ground of a percentage. Uncertainty prevailed, therefore, as to the basis of taxation and gross adulteration flourished until scientific safeguards were introduced.

The chief substances with which the chemist is at present concerned from the Revenue point of view are the following: (1) liquids containing alcohol; (2) tobacco; (3) sugar; (4) tea and cocoa; (5) dyestuffs, under the Dyestuffs (Import Regulation) Act, 1920; (6) substances taken under the Safeguarding of Industries Act, 1921.

(1) *Liquids containing alcohol.*—On imported wine Richard I. imposed a duty, and as time went on complications were caused by the introduction of imposts for various purposes, including reprisals.

Acts were passed, as in the time of Charles II., for preventing the reprehensible practices of mixing wine and vitiating it with other substances such as cider, sugar, herbs and vitriol; it is still forbidden to mix wines of different sorts.

The difficulty of distinguishing the strength of alcoholic liquids is apparent in the older enactments, when, for example, the Legislature describes brandy as a 'strong water perfectly made imported from beyond the sea,' and it was not until the reign of William III. that they were assessed, if not in proportion to their strength, at least in some relation

thereto. The first step was their separation into 'single' and 'double' proof, a rough and inconclusive one, but accounting for the use of a term still recognised as that on which the full statutory rate of duty is leviable.

For charging Revenue the gallon was first taken as a measure in 1825, but definite alcoholic strength was not introduced as a basis until 1860, under a treaty with France, while a little later, in 1862, Parliament distinguished between wines above and below 26 degrees of proof spirit, this figure being raised in 1886 to 30 degrees.

The want of some accurate method of test had been felt, and it is interesting to follow the gropings after a method for recognising a standard strength of alcohol. Thus observations on the surface tension of spirits were employed, for Postlethwaite in 1751 described as a mark of their being up to proof the length of time elapsing before bubbles disappear from the surface of the liquid contained in a glass tube which had been shaken, but as he believed this method may be falsified, he recommended for more accurate work ' the essay instrument, or hydrostatical balance,' although for business men it would be sufficient to burn a measured quantity of the spirit in a metal cylindrical vessel immersed in cold water, and measure the remainder, which should be equal to half the original volume, if the spirits were proof. Although ' Boyle's bubble ' had been described in 1675, and Moncony's areometer in 1679, the first instrument generally adopted by the Revenue in 1730 was the hydrometer of Clarke, legalised in 1787. It is complicated, however, and its temperature correction by ' weather weights ' was unsatisfactory, so that Parliament gave instructions for ' proper experiments to be made.'

At the request of the Government to the President of the Royal Society, Sir Charles Blagden (Secretary) and one of the clerks, Mr. George Gilpin, undertook to make experiments on the specific gravity of alcohol and water in varying proportion. These experiments, conducted with exemplary care and ability, were reported to the Royal Society in 1790, 1792, and 1794, and formed the basis for the tables of Sikes, whose hydrometer became the sole legal instrument in 1818, and is still in use. These tables remained legal for nearly a hundred years, but in 1916 were replaced by a new and extended set, prepared under the supervision of Sir Edward Thorpe at the Government Laboratory, whence also in the same year were issued comprehensive tables of spirit strengths for use with pyknometers, as these had shortly before been legalised for alternative use in the determination of alcohol. Both of these sets of tables were founded on the definition of proof spirit contained in the Act of George III., which is, that spirit which at the temperature of 51° Fahr. weighs exactly 12-13 parts of an equal measure of distilled water. In other words, it contains 49·28 parts by weight of pure alcohol and 50·72 parts by weight of distilled water.

As these tables refer only to alcohol-water mixtures, all disturbing substances must be removed before the strength of liquids is determined by hydrometer or pyknometer. The methods of freeing spirit in commercial articles from everything but water were investigated and laid down by the Government Laboratory in 1903 by Thorpe and Holmes.

From the point of view of trade it is highly important to have free use of ethyl alcohol, while from that of the Revenue it is essential to prevent the use of such duty-free spirit as a beverage. The most effective means

to meet both requirements is to denature spirit which is to be delivered duty-free for trade purposes, and the question of the choice of a suitable denaturant is by no means easy. So long ago as 1856, the Government Chemist of the day, Mr. Phillips, proposed the addition of 10 per cent. of crude wood naphtha, and this has been found satisfactory for most purposes. The proposal was submitted to and approved by three well-known chemists of that day, Graham, Hofmann, and Redwood, and this present year circumstances have necessitated the addition of a further nauseating ingredient, pyridine, in addition to mineral naphtha which was added in 1891. Mineralised methylated spirit which is sold without Revenue control, excepting that a licence is needed, contains this proportion, industrial methylated spirit 5 per cent., and power alcohol $2\frac{1}{2}$ per cent. on the alcohol.

That some misunderstanding exists as to the facilities available for the use of alcohol in commerce in the United Kingdom appears from an article recently communicated to the Ottawa Section of the Society of Chemical Industry, in which are contrasted a considerable number of compositions approved in Canada with the apparently small number legalised in Great Britain. It might be well, therefore, briefly to indicate the position, in order to make clear the facilities that are available.

Mineralised methylated spirit consists of a mixture of 90 parts of alcohol, $9\frac{1}{2}$ parts of wood naphtha, and half part of crude pyridine, together with $\frac{3}{8}$th of 1 per cent. of mineral naphtha and 0·025 of an ounce of methyl-violet dye in each 100 gallons of the mixture. It is sold under licence, but is otherwise unrestricted and duty-free.

Power methylated spirit, prepared in accordance with the following formula : 92 parts of alcohol, 5 parts of benzol, 0·5 part of crude pyridine, and 2·5 parts of wood naphtha, together with 0·025 of an ounce of Spirit Red III. dye in each 100 gallons of the mixture, is also sold without restriction and freedom from duty when mixed with 25 per cent. of hydrocarbons or denatured ether or some other substance approved by the Commissioners of Customs and Excise.

Industrial methylated spirit, consisting of 95 per cent. of ethyl alcohol and 5 per cent. of wood naphtha, can be obtained for the arts and manufactures under the authority of the Board of Customs and Excise, under bond and certain not very onerous restrictions. Between three and four million bulk gallons are annually used for the making of such products as varnishes, linoleum, soap, solid medicinal extracts, ether, toilet preparations for external use, fine chemicals, photographic plates, dyes, surgical dressings, fireworks, and for many other purposes, including its use in the chemical laboratories of colleges, schools and works, and for preserving museum specimens. It is free from duty, but must not be present in an article capable of internal use, either as a beverage or a medicine.

Duty-free pure alcohol is allowed by the Board of Customs and Excise for scientific purposes to universities and public institutions for teaching and research, and specially denatured alcohol in arts and manufactures in which the use of the industrial methylated spirit is unsuitable.

The pure alcohol is allowed to colleges and public institutions for teaching and research purposes without any onerous conditions beyond the keeping of a stock account. Pure methyl alcohol is permitted by the Board of Customs and Excise to be used duty-free in arts and manufactures

under regulations similar to those for industrial methylated spirit, and is largely used in the manufacture of formaldehyde, of methyl derivatives among dyestuffs and fine chemicals, and for the purpose of crystallisation.

The specially denatured alcohol, also free from duty, is allowed to manufacturers under restrictions compatible with the safety of the Revenue, a very wide choice of denaturants being permitted. When, as frequently happens, a suitable denaturant is found in some intermediate product, or acid used, or produced during the manufacturing operations, or when the alcohol is a constituent of some mixed solvent, permission is the more readily granted for its use. An example of progressive policy in the use of pure spirit is the recent decision of the Board of Customs and Excise to allow the use of pure ethyl alcohol denatured with 2 per cent. of pure methyl alcohol in the production of insulin, without onerous Excise restrictions. It is understood that the recent action of the Board of Customs and Excise has been received with satisfaction by the Association of British Chemical Manufacturers. The quantity of pure and specially denatured alcohol used during last year was about half a million gallons.

In the case of duty-paid spirits used for medical purposes, such as the preparation of tinctures, &c., and for scientific purposes in chemical laboratories, a rebate is allowed under the Finance Act of 1920, amounting to about 80 per cent. of the duty.

While the responsibility rests on the Board of Customs and Excise of safeguarding the illicit use of alcohol, chemists have been represented on such commissions as that of the Industrial Alcohol Committee of 1905, whose recommendations led to the Revenue Act of 1906, in which the proportion of wood naphtha was reduced to 5 per cent., permission being also given for the payment of an allowance of 5*d.* per proof gallon or about 8*d.* per bulk gallon on British spirits used for industrial purposes, in consideration of the increased cost of the spirits owing to Excise restrictions.

An important alcoholic liquid that has been liable to imposts from the time of Charles II. is beer, and it was charged according to its strength or weakness as judged by the palate. After the application of science to brewing about the middle of the eighteenth century, the saccharometer was introduced, the pattern due to Bate being still in use for Revenue purposes. In 1850 an investigation made by the then Government Chemist, Mr. Phillips, and his assistant, Mr. Dobson, established a quantitative relationship between the proportion of alcohol produced in the process of fermentation and the solid matter previously in solution in the worts that had been fermented, and tables were prepared for use in determining the original gravity of the beer, *i.e.* the specific gravity of the worts before fermentation had begun. These tables, after verification by Professors Graham, Hofmann, and Redwood, were employed in the Revenue service until 1914, when they were superseded by revised ones prepared by Sir Edward Thorpe and Dr. Horace T. Brown, these being rendered necessary mainly owing to the employment in brewing of many substitutes for malt unknown in the earlier days. As a rapid means for determining the original gravity the immersion refractometer is constantly in use in the Government Laboratory. This laboratory also furnished the scientific evidence for the Inland Revenue Act of 1880, which enabled brewers to use a great variety of substances for brewing.

(2) *Tobacco.*—Not long after its introduction Elizabeth imposed a small duty on tobacco, which under James I. met with not only his famous Counterblast, but an increased duty of 6*s.* 10*d.* a pound. Although Charles I. continued its repression, and the Puritans regarded its use as 'profanity,' the snuff-box became in the time of Queen Anne a necessity of the fashionable world. A regular trade sprang up in preparing substitutes from various leaves, and numerous enactments proved incapable of preventing smuggling and adulteration. It was recognised that systematic chemical and microscopic examination had to be applied to the problems arising from this adulteration, and in 1843 a laboratory, which ultimately grew into the Government Laboratory, was erected to check it, with the result that this form of fraud was almost entirely stamped out. A strict watch is still maintained on all tobacco for home use or for export, both from the point of view of absence of foreign materials and of its hygroscopic condition, as the Revenue charge is based on the latter. Chemical control is exercised over the use of preservatives and the denaturing of tobacco before it can safely be allowed out of Revenue control.

(3) *Sugar.*—In the reign of James I. the importation of sugar was already sufficiently large to make it worth while to impose a duty on it, until at the beginning of the nineteenth century this amounted to 30*s.* a hundredweight. Before 1875, when the duty was abolished, disputes had arisen as to its proper assessment on the basis of description and character. When it again became dutiable in 1901 an extended classification was based on the polariscope scale, and sugars in numerous preparations had to be determined chemically. This has raised several difficult questions of chemical procedure, especially when natural as well as added sugars are present.

(4) *Tea and cocoa.*—Attempts were made in 1777 to stop the adulteration of tea with foreign and exhausted leaves and other matter, but it was not until 1875 that the Sale of Food and Drugs Act placed on the Revenue authorities the responsibility for examining tea on importation. This is done on an extended scale by the application of chemical, microscopic, and practical tests. There has been, however, no imposition of standards in the United Kingdom, as is the case in Canada and the United States.

The duty, and the drawback on the duty, on cocoa preparation has introduced chemical problems into the system of Revenue control, some of them of considerable difficulty, as, for example, those connected with the use of substitutes for the natural cocoa fat.

(5) *Dyestuffs, under the Dyestuffs Import Regulation Act,* 1920.—The importation of dyestuffs under this Act is controlled by a Dyestuffs Advisory Licensing Committee, on which distinguished chemists represent the science.

Importation of synthetic dyestuffs and intermediates is prohibited except under licence, and although the individual substances leave little room for doubt, more difficult questions come before the Government Laboratory in the case of substances containing a coloured ingredient.

(6) *Substances taken under Safeguarding of Industries Act,* 1921.—Part I. of this Act imposes an *ad valorem* duty on the products of certain 'Key' industries, of which the fine-chemical manufacturing trade is one. After the Act had passed into law, the Government Laboratory became concerned with the chemical aspect of that section which has gained

notoriety through legal inquiries involving the precise significance of chemical and technical terms. But apart from such matters, many difficult chemical problems have arisen in determining the composition of the great variety of chemical substances imported. Thus it has proved a task of some magnitude to deal with about 8,000 subjects per annum, when their examination may include the quantitative determination of the ingredients of materials such as synthetic perfumes, photographic developers, medicines, colloidal preparations, alkaloids, &c. The grade of a specified material has also frequently to be assessed, and this involves a special knowledge of its manufacture and use.

The effect of the war was generally to increase the amount of existing duties and to impose fresh ones. The former condition led to increased vigilance in the chemical control on account of the introduction of substitutes to replace the dutiable substances; the latter were imposed as a post-war condition and are described above. In connection with the war-time prohibition of exports, not only of munitions but practically of all useful commodities, the services of the Government Laboratory were required to decide as to the nature of about 20,000 substances, including cases in which the prohibited goods were skilfully disguised.

For all matters involving chemical advice the Board of Customs and Excise applies to the Department of the Government Chemist, who maintains on his staff for this section of the work a sufficient number of chemists and assistants to make the necessary investigations and deal with the chemical points at issue, as well as to carry out the necessary practical work, both in London and at several of the ports. This aspect of the work of the Government Laboratory involves a knowledge of Revenue law and precedent as well as an intimate acquaintance with a large range of chemical manufacture.

The importance of chemical control in safeguarding the Revenue is obvious. With increase in the number of subjects brought under supervision, the greater refinements and accuracy demanded, the investigation of new processes, and the amount of chemical work, the number of chemists is rapidly increasing.

Health.

The earliest legislation in respect of food dealt with articles from the Revenue standpoint rather than from that of safeguarding users against adulteration. Thus, the Adulteration of Coffee Act of 1718 refers to evil-disposed persons who make use of water, grease, butter and such-like materials for addition to coffee, 'whereby the same is rendered unwholesome and greatly increased in weight, to the prejudice of His Majesty's Revenue and the health of his subjects.' Similarly, the Tea Act of 1730 refers to the use of various materials and operations for sophisticating tea, 'to the prejudice of the health of His Majesty's subjects and the diminution of the Revenue.' The Tea Act of 1776, which deals specifically with the preparation of other leaves for use in imitation of tea, gives as an additional reason 'the injury and destruction of great quantities of timber woods and underwoods.'

Since this legislation was mainly for the prevention of fraud on the Revenue, it was left to the Crown to take such steps as were considered necessary to ascertain the purity of the articles in question. To this end

the Inland Revenue Laboratory, which was established in 1842 primarily for testing tobacco, became also the laboratory for the analysis of dutiable foods, such as tea, coffee, pepper. In this connection it is of interest to note that the Government at times sought assistance from distinguished chemists not on its staff, as when Thomas Graham, at University College, London, carried out for the Board of Inland Revenue an inquiry into the chemical means of detecting vegetable substances mixed with coffee for the purposes of adulteration. Among the early pioneers in the chemistry of food may be mentioned Dr. Hassall, who was the analyst of the 'Lancet Sanitary Commission,' and published the reports of that body under description of 'Food and its Adulteration.'

Besides the enactments with regard to certain dutiable foods referred to above, legislative action was taken with respect to bread, the Bread Act of 1822 dealing with the sale of bread in London and district, and that of 1836 with the sale of bread outside the London area. There was no provision for analytical examination of samples under these Acts, which still remain in force.

By the efforts of Lyon Playfair on matters of sanitation and the work of the Royal Commission on the Health of Towns of which he was a member, public opinion was being awakened during the 'forties to the social importance of the health of the community, a movement in which the Prince Consort took an enthusiastic part. This led to the Commission of 1869 and the foundation of the Local Government Board, through which the safeguarding of public health in England was systematically organised. From this Board and its successor, the Ministry of Health, a series of useful reports on questions of food have issued, most of which have involved chemical investigations.

In 1855 and again in 1856 a Committee was appointed by Parliament to inquire into the 'Adulteration of Food, Drinks and Drugs.' It was evident to these Committees that some provision for the chemical analysis of samples was necessary, but they made no provision for samples to be taken. This and other matters were provided for in an amending Act, which came into force in 1872. A Select Committee of Parliament was appointed in 1874 to inquire into the working of these Acts, and as a result of their report another Act, that of 1875, was substituted. By this Act the Local Government Board was given power to require evidence of competence from analysts, and the Inland Revenue Laboratory (now the Government Laboratory) was appointed as the authority to which Courts of Law could refer disputed cases.

The Act of 1875 has been amended and extended by the Acts of 1879 and 1899, and other Acts have been associated or incorporated with it, such as the Margarine Act of 1887 and the Butter and Margarine Act of 1907, the whole series being referred to collectively as the Sale of Food and Drugs Acts, 1875-1907.

The provisions in the above Acts affecting chemists may be summarised as follows: (1) the appointment of public analysts by local authorities is compulsory; (2) the Ministry of Health and the Ministry of Agriculture (when the interests of agriculture are in question) have power to step in if the local authority fails to utilise the services of the public analyst; (3) the appointment and dismissal of a public analyst by a local authority are subject to the approval of the Ministry of Health; (4) the analyst must

afford the Ministry evidence of his competence for the work. It is the practice of the Ministry to accept for such purpose the Diploma of the Institute of Chemistry, together with the Certificate of that Institute in Therapeutics, Pharmacology and Microscopy.

The position of the Government Chemist in the administration of the Acts is as follows: (1) the Acts provide that in the hearing of any complaint in a court of justice the magistrates must, at the request of either party, and may themselves without any previous request, send the reserved portion of the sample to the Government Chemist for analysis. This provision is taken advantage of in a number of cases each year, and gives rise to a considerable amount of interesting work relating to methods of analysis, the alteration in food on storage, and the figures to be taken as standards for genuine articles. The necessity for such investigation is at once apparent in the case of milk, since samples cannot under ordinary circumstances reach the laboratory before the expiry of at least three or four weeks, and the fermentation that has taken place in this time has resulted in the loss of solid matter.

(2) The Acts provide for the examination at the Government Laboratory of samples of imported tea, margarine, and various dairy products, the object being (*a*) to prevent adulterated food of this character entering the country, and (*b*) to ascertain whether it conforms to the standards laid down for such food.

It may be pointed out that there is nothing in the United Kingdom corresponding with the series of food definitions and standards which exist in some of our Colonies, and in a marked way in the United States. The main provisions of these Acts are briefly that (1) no person shall mix any article of food with any ingredient so as to render the article injurious to health, and (2) no person shall sell to the prejudice of the purchaser any article of food which is not of the nature, substance and quality demanded by such purchaser. A few definitions and standards are, however, given in the Acts, and these have been added to by Regulations under the Acts, or by Regulations made under the Public Health (Regulations as to Food) Act, 1907, the Licensing Act, 1921, and the Milk and Dairies Act, 1922. Before regulations on questions of limits have been issued, it has been customary for the Crown to institute an inquiry into the particular subject.

A brief summary of the definitions and standards thus fixed is as follows: (1) the strength of spirits must not be reduced more than 35 degrees under proof; (2) standards have been fixed for milk, separated milk, condensed and dried milks; (3) limits have been set up for water in butter, milk-blended butter and margarine, and for butter fat in margarine; (4) the addition to milk of water, preservative, colouring matter, separated or reconstituted milk is prohibited; (5) cream must not be mixed with a thickening substance, and the conditions with regard to the addition of preservative to it have been laid down.

In its care for the purity of drinking water the State has made several enactments. It may be said that this country led the way as the result of the great work of Frankland in devising means for determining the potable qualities of water, and in pressing for pure supplies. An enormous volume of useful work was carried out by the Royal Commission on Sewage Disposal of which Ramsay was a member. This sat from 1898 until 1914, when it dissolved, having projected further work on industrial effluents

and their effect on river water, work which is just recently being followed up by an Advisory Committee to the Ministry of Agriculture and Fisheries.

The contamination of the atmosphere is a subject of concern to the Ministry of Health working under Acts from 1863 onwards. Limits have been set to the discharge of noxious and offensive gases, and the control is in the hands of a number of chemical inspectors, who have in addition carried out a large number of investigations of importance to general health and to industry. The contamination of the air in cities is watched by the Meteorological Office, which records the quantity of soot falling in different parts of the country. By such means the public conscience is being awakened to the necessity for carrying out work on the provision of a smokeless fuel, a subject engaging the attention of the Government Fuel Research Station.

Chemical control is also concerned with the question of danger to health arising in certain trades, such as that of the manufacture of matches, in which red was substituted by law for white phosphorus, with the limitation of lead in glazes, with the nature of the gases in mines, and with manufactures in which poisonous substances such as nitrobenzene and nitrous fumes are produced.

In 1900 there was a serious outbreak of sickness attributable to poisoning by arsenic, and a Royal Commission was appointed to inquire into the cases and to ascertain by what safeguards the introduction of arsenic to food could be prevented. A very large amount of chemical work was carried out in connection with this inquiry, and considerable attention was paid to the methods for the detection and examination of arsenic. Among those contributing specially to the problems may be mentioned Dr. George McGowan, the Government Laboratory, and a Joint Committee of the Societies of Public Analysts and Chemical Industry. At the Government Laboratory an electrolytic apparatus was devised in which the use of zinc for the production of hydrogen was not necessary. This apparatus has been modified by replacement of the expensive platinum cathode originally used by lead coated with mercury, which has been found to give very satisfactory results.

It was not until the end of 1916 when the war had continued for more than two years that the control of the food supply of the country passed into the hands of a Ministry of Food. In the meantime much work of a scientific nature had been done in the way of endeavouring to educate the people on food values. A pioneer in this direction was Professor W. H. Thompson, who occupied the Chair of Physiology in Trinity College, Dublin, and who became later Scientific Adviser to the Ministry of Food. He was unfortunately lost in the sinking of the Irish mail boat in which he was a passenger. Thompson communicated to the Royal Dublin Society early in 1915 an important paper dealing with the energy value and chemical constitution of foods, subsequently published as a pamphlet under the title of 'The Food Value of Great Britain's Food Supply.' The question of the food supply of the United Kingdom was receiving attention in 1916 from a Committee of the Royal Society which included among its members distinguished chemists, and at the request of the Board of Trade the Committee drew up a report on the food supply in which much of Thompson's work was incorporated. It is interesting to note that in the main the values given by Atwater in the 'Chemical Composition of American Food

Bri

Y IN THE UNITED KINGDOM.

AGRICULTURE

ORGANISED RESEARCH AND GOVERNMENT ASSISTED RESEARCH

17

17

18

Board of Agriculture

[Davy — Lectured on Agriculture]

18

[Lawes] — Rothamsted

[Gilbert] — Rothamsted

18

[Voelcker] Woburn

18

Government Laboratory—Referee on Composition of Fertilisers and Feeding Stuffs

Hall
Russell

19

Assistance — from Development Commission

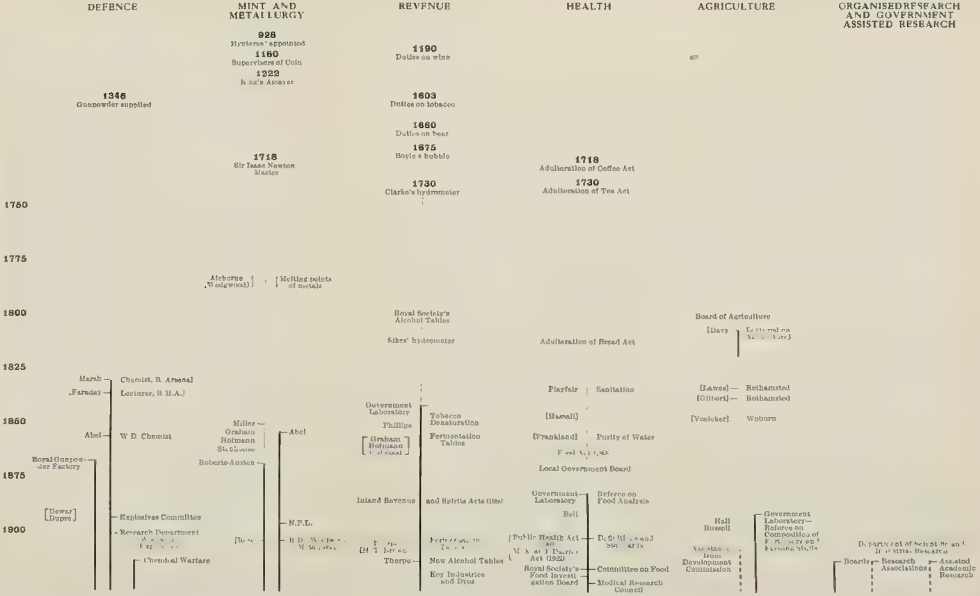
Department of Scientific and Industrial Research

Boards — Research Associations — Assisted Academic Research

Thick line indicates definite laboratory equipment.

To

CHART SHOWING DEVELOPMENT OF STATE'S ACTIVITIES IN CHEMISTRY IN THE UNITED KINGDOM.



Thin dotted line indicates continuity of some Department of State. Thick dotted line indicates partial assistance given by State. Thick line indicates definite laboratory equipment.

To face p. 72.]

Materials' were followed in the calculations. There can be little doubt that the decision of the Government to recover a larger proportion of the grain for human food in milling wheat, and to restrict the use in brewing and distilling of materials capable of use as food, arose from the suggestions put forward by this Scientific Committee.

The chemical examination of the enormous quantities of food, together with the inspection of the packing and the testing of materials used for the purpose, forwarded overseas from this country for the Army in the war was entrusted to the Government Laboratory. Chemists were established at the various receiving depots, and all goods delivered by contractors were inspected, and, if considered necessary, sampled and analysed as to their conformity with specification. The chemist reported upon each delivery before the Army authorities proceeded to issue it.

The Medical Research Council, now under a Committee of the Privy Council, deals with subjects coming within the province of biochemistry, and the organic chemist has here an opportunity for preparing substances which the knowledge now available indicates as likely to be of value in combating, for example, diseases due to parasites in the bloodstream.

Agriculture.

The connection of the State with scientific agriculture goes back to the beginning of the nineteenth century. The period from 1770 to 1820 was one of great activity in agricultural development. It was then that several of the oldest agricultural societies were formed, and the Chair of Agriculture and Rural Economy founded in Edinburgh University.

The first Board of Agriculture was formed in 1793, and it was to this Board that Humphry Davy, himself one of its members, delivered during the years 1802-1812 the courses of lectures which were afterwards published under the title of the 'Elements of Agricultural Chemistry.' Davy in his introductory remarks dealing with the object of the lectures sets out clearly what he understood by Agricultural Chemistry—it 'has for its object all those changes in the arrangement of matter connected with the growth and nourishment of plants; the comparative values of their produce as food; the constitution of soils; the manner in which lands are enriched by manure, or rendered fertile by the different processes of cultivation.' This statement sets forth the position to-day, and in the progress that has been made towards the attainment of these objects the chemist has played an important part.

Although Davy quotes the results of his chemical work on a series of grasses, no great advance was made for many years, and when it did come it was at the instance of private enterprise. To John Bennet Lawes, the founder of Rothamsted, is due the initiation of experiments which began in 1834 and have continued uninterruptedly until to-day. Joseph Henry Gilbert joined Lawes in 1843, and the association of the two was not broken until Lawes' death in 1900. The cost of this experimental station was borne entirely by funds supplied by Lawes. When Gilbert died in 1901, Sir A. D. Hall became director, and he was succeeded in 1912 by the present director, Sir John Russell.

The next experimental station in England was that founded by the Royal Agricultural Society on the Duke of Bedford's estate at Woburn

under the direction of Dr. A. Voelcker, and now carried on by his son Dr. J. A. Voelcker. The Royal Agricultural College at Cirencester was founded in 1845.

The development of the scientific study of agriculture was thus left largely to such institutions as that of Rothamsted, and to certain agricultural colleges which did not receive State aid.

The first legislative action on behalf of agriculture with which the chemist was concerned was an Act for the protection of the agriculturist against fraud from the purchase of inferior or worthless manures and feeding stuffs. By the Fertilisers and Feeding Stuffs Act of 1893, superseded by the Act of 1906, the seller of artificial fertilisers and certain classes of artificially prepared feeding stuffs was compelled to give with the goods an invoice guaranteeing the percentages of specified constituents on which the value of the article depended, and county authorities were required to appoint agricultural analysts for the purpose of checking the statements on the invoice by analysis of samples. The Board of Agriculture also appointed a chief analyst who was required to analyse the reserved samples in cases where discrepancies were of such a nature as to lead to the possibility of proceedings in Court.

It will thus be seen that, with the exception of the encouragement given to the work of Davy, the first State action was not towards development of agriculture, but for the repression of fraud. There were, however, movements from time to time in the direction of scientific inquiry into problems connected with agriculture, such as an investigation into the effect of food and breed on milk, and an inquiry into the efficiency of sheep dips, with both of which the Government Laboratory was closely associated.

No systematic educational work in scientific agriculture was attempted in Great Britain before 1909, when an Act was passed allocating annually the sum of £500,000 for 'aiding and developing agriculture and rural industries by promoting scientific research, instruction and experiments in the science, methods and practice of agriculture (including the provision of farm institutes).' Under this Act, a system of agricultural research was framed, based on university and on research institutions like Rothamsted, and linked up with the agricultural colleges. The scheme formulated enabled the Development Commissioners appointed under the Act to form new institutes as well as to extend the existing ones. Rothamsted was largely extended, and increased facilities afforded for work on Plant Physiology (Imperial College), Plant Breeding (Cambridge University), Animal Nutrition (Cambridge), Dairying (Reading), Animal Pathology (Royal Veterinary College), and on similar subjects. In many of these the chemist was essential. Another part of the scheme was the foundation of scholarships awarded to selected graduates of universities, tenable for a three-year course of research. In certain selected teaching institutions technical advisers for farmers were appointed, and researches not capable of being pursued at an institute were maintained elsewhere.

The provision of this scientific work for the benefit of agriculture is carried out by the Commissioners through the medium of the Board of Agriculture, with which policy is discussed and details arranged. It represents the first co-ordinated attempt by the State in the United Kingdom to secure a comprehensive scientific study of the problems of agriculture, and the first systematic endeavour to apply scientific method to

the development of agriculture. Results followed at once, and as an illustration it may be pointed out that in the eight years from 1912 to 1920 Rothamsted issued, in spite of the adverse effects of the war, 75 scientific papers, published eight books, and contributed numerous articles for farmers and teachers, and the Cambridge Animal Nutrition Station also published 60 papers in the same period. Other institutes also contributed to knowledge on this subject.

During the war, agriculture in this country was affected in several ways —for example, by (1) shortage of the usual feeding stuffs for cattle, and (2) shortage of fertilisers, particularly potash and nitrogen, both as nitrates and ammonium salts. At the same time there was a demand for an increased production owing to the diminished supplies of essential foods from abroad.

The attention of chemists was directed to these points. Fortunately the research institutes provided by the funds of the Development Act referred to above were in existence and available for making investigations. Thus the staff at Rothamsted under Russell gave special attention to the shortage of manures and prepared monthly notes for the guidance of farmers, while the Animal Nutrition Institute at Cambridge under T. B. Wood provided monthly notes on the uses of available feeding stuffs. In the latter part of the war, conferences were held weekly at the Food Production Department in which research workers from the institutes took part. These meetings had such value that the Ministry of Agriculture and Fisheries have now constituted an Advisory Council in Agricultural Research at which the directors of the institutes meet periodically to review the progress being made.

When the war-time requirements of nitrogenous fertilisers are considered, it is significant that the production of nitrogen in the form of ammonia showed no increase in the first years of the war, and only a six per cent. increase in 1917 over 1913. The restriction of nitrate supplies for munitions caused a greater demand for nitrogen in the form of ammonia, and it may be expected that in the future even larger quantities will be needed. The Nitrogen Products Committee estimated that the possible demand in the near future for artificial nitrogenous fertilisers for the United Kingdom would be 100,000 tons of nitrogen, or four times the quantity used in 1913.

Of the fertiliser ammonium sulphate we produced before the war five times as much as we required for our own use, but we imported also over 100,000 tons a year of sodium nitrate from Chile. During the war the importation of this salt was quadrupled and nearly all was taken up for munitions, being converted into nitric acid for the purpose of nitrating glycerine, cotton, toluene and phenol, and made into ammonium nitrate for the explosive amatol. All our explosives therefore depended on the importation of Chile saltpetre, a condition of affairs which gave rise to great anxiety, especially at the height of the submarine menace. Although we still had sufficient ammonia, there was no plant available for oxidising it to give the nitric acid required. As no sodium nitrate could be spared for agriculture, its place was taken by ammonium sulphate, of which increasing quantities were used for manuring the soil to obtain increased productivity. At the same time this salt was being increasingly used for making ammonium nitrate, so that the time approached when, in place of the ample margin before the war, a shortage of ammonia was in sight.

The claim of munitions on sulphuric acid also materially reduced the quantity of ammonium sulphate as well as of superphosphate by about 40 per cent., and chemists had to devise means for using nitre-cake in its place in the manufacture of these fertilisers.

Anxiety as to the want of capacity of the country for fixation of atmospheric nitrogen had led in June 1916 to the foundation of the Nitrogen Products Committee, the results of whose labours will be found in a massive Blue Book full of information on statistics, on processes, and on the comparative merits of methods for developing power. A staff of chemists and physicists attached to the laboratory of this Committee were actively engaged on investigations on the conditions of manufacture of ammonia by the Haber process, as well as in determining the physico-chemical constants of the gases involved. Much valuable work was accomplished both on the combination of hydrogen and nitrogen and also on the oxidation of the product to nitric acid, so that the Committee was able to recommend the erection of a trial plant in February 1917, and by October of that year the Department of Explosives Supply recommended the process worked out for adoption in a national factory, and a start had been made towards its erection at the end of the war.

This project was taken over by Synthetic Ammonia and Nitrates, Ltd., which has continued the research work and erected the large-scale plant. It is satisfactory to be able to announce that, instead of being about the only great nation not engaged in the fixation of nitrogen from the air, we have now in Great Britain a plant producing at the moment 150 tons of synthetic ammonia a week. From the point of view of agriculture as well as of national defence, this cannot fail to afford a fresh, if somewhat delayed, confidence.

The shortage of potash supplies was apparent soon after war broke out, since nearly all potash came from Germany. Attention was immediately drawn to other possible sources of supply and to means whereby the potash in stable combination in the soil might be made available. Russell at once called attention to the potash salts in the ash of seaweed, bracken, hedge-clippings, wood-waste, and similar substances, and advised as to the best methods for utilising them. He also advised the use of lime, and in certain circumstances of sodium salts, whereby potash in the felspars and clays became available.

Numerous suggestions put forward as to possible sources of supply of potash were inquired into. In one interesting case, where a small-scale plant was put into operation under the supervision of the Government Laboratory, a good yield of potash was obtained from felspar, but the process involved the production as a by-product of so large a quantity of an inferior quality of cement that unless a market could be obtained for this there was no possibility of working the process successfully.

A source of supply that was used to a certain extent was the flue-dust of furnaces, which was found to contain a fair though variable quantity of potash. Considerable developments were made by Mr. Kenneth Chance, of the British Cyanides Co., in the direction of obtaining from the ores dealt with in the United Kingdom a large supply of potash, and an extensive scheme of operation was contemplated before the Armistice.

Another direction in which supplies became restricted was in respect of phosphatic manures. Importation of bones, mineral phosphates, and guanos,

owing to war conditions, could not be maintained, and, owing to the demand for sulphuric acid for essential munitions of war, the supply for manufacture of superphosphate was strictly limited. Hence attention was directed to the examination of the results obtained by using finely ground natural mineral phosphates and basic slag. These insoluble phosphates were found to possess a considerably greater value as fertilisers than they had been given credit for.

The shortage of food-stuffs for cattle arose partly from decreased imports, particularly of linseed, cotton seed, and grain, and partly from causes within the country, as for example the dilution of flour with maize and other cereals and the milling of the grain to obtain an increased percentage of flour for human food, whereby the quantity of milling offals was reduced. The attention of chemists was at once directed to the question of new or hitherto little-used food-stuffs. For some years prior to the war the importation into Continental countries, particularly Germany and France, of valuable oil-seeds had been rapidly increasing, thus providing oils for margarine manufacture and valuable cakes and meals as food for cattle. The case of palm-kernels, a valuable source of oil and cake, is a striking one, for British West Africa exported before the war about 230,000 tons, of which 35,000 tons came to England and 181,000 tons to Germany, and a similar condition applied to copra, earth-nuts, and sesame seed. These and many other seeds began to be diverted to the British market, and the cakes or meals, after examination of feeding value, formed a useful addition to the food supplies, as was illustrated by the great increase in the manufacture of margarine.

Home supplies were also explored, materials which had hitherto been discarded were tried, and waste material from a variety of sources was utilised. In all this the work of the chemist was essential. The ascertaining of the composition of the material, of the digestibility coefficients of the various constituents, and of the feeding value of the material was the contribution of the chemist to this great problem of the nation.

Since many of the war-time expedients mentioned above were of a makeshift character, it is not surprising that they did not survive when normal economic conditions arose. Thus, when sulphuric acid again became available, the troublesome use of nitre-cake was abandoned and blast-furnace flue-dust was no longer collected. It was disappointing that the nitrogen fixed in the large surplus stocks of explosives, both in the form of nitric esters and of nitrogen compounds, could not profitably be utilised. Many of the difficulties were overcome in the case of the nitric esters by the application of a process of alkaline hydrolysis, but the attempt was abandoned on account of the difficulties which arose during process in freeing the product from poisonous impurities and in putting it on an economic basis.

The war-emergency work has had some lasting effects, of which may be mentioned the development of a process for making 'synthetic farmyard manure,' the increased use of basic slag as a phosphatic fertiliser, and the increased attention that is being devoted to the newer nitrogenous fertilisers, more particularly those produced by fixation of atmospheric nitrogen.

The lessons of the war have not, however, been entirely lost. The last report of the Development Commissioners, for the year ended 31st March, 1923, shows advance in every direction. In addition to the sum available

from the Development Fund of the Act of 1909, it was possible to make increased grants owing to the money received under the Corn Production Acts (Repeal) Act, 1921. The special fund enabled grants to be made for additional research, as, for example, the extension of the advisory scheme in connection with agricultural research, the provision of scholarships for children of agricultural workers, and the endowment of a Chair in Animal Pathology at Cambridge. In order to prevent overlapping and to secure co-ordination, the Development Commissioners are working in consultation with the Medical Research Council and the Department of Scientific and Industrial Research.

It may be said that the greater part of the work on agricultural chemistry since the war has been of a fundamental nature, the results of which have not yet become capable of translation into agricultural practice, although they may be expected to exert ultimately a powerful influence on farming.

Other Activities.

In addition to the activities that have been grouped under the respective headings, there are many others bearing on State problems which have occupied the attention of chemists.

Thus, expeditions, such as that of the *Challenger*, have been fruitful in results of chemical work. The investigations of Dittmar on the composition of sea-water and of Murray on mineral phosphates may be recalled in this connection.

For data on the chemical composition of rocks the Geological Survey is indebted to the work of Percy, Dick, and Pollard, and for work on the formation of igneous rocks to Teale, Harker, and Flett. The remarkable experiments of Sir John Hall on rock-formation at the beginning of the nineteenth century have been described in a recent British Association address. On several occasions the choice of building-stone, especially for the Houses of Parliament, has been before groups of geologists and chemists, especially with respect to the action of atmospheric impurities, and although the causes of decay are fairly clear, its arrest still forms a difficult problem.

The difficulties in selecting colours sufficiently fugitive to prevent the removal of obliteration marks from postage and fiscal stamps were to a large extent solved by the activities of Warren de la Rue.

Investigations on such matters as the above for various Departments of State form part of the work of the Government Laboratory, which in addition, during the war, had to advise concerning the conservation of materials, the control of imports and exports by the War Trade Department, and on the nature of contraband goods.

Organised Applied Research.

In the middle of 1915, at a time when our shortage of many essential materials brought out the need for the application of more scientific methods to our industries, if we were to succeed in competition with other countries after the war, the Department of Scientific and Industrial Research was founded. It set out to assist firms in an industry to co-operate with one another and employ a staff of scientific men to solve their problems and develop their industry, to assist other Government Departments desirous of having investigations carried out, to organise

research into problems of practical utility of wide importance, and to foster the prosecution of researches in pure science. With the exception of the last, these aims can be considered as coming under the designation of organised applied research. The Department has always strongly insisted that it is this type of work only that it seeks to organise, the assisted worker in pure research being left entirely free to follow his bent.

As regards scientific policy, the Minister in charge of the Department is advised directly by a Council of independent scientific men, and these are represented also on the various Boards and Committees entrusted with the supervision of such investigations as are directed by the Department itself.

Research Associations.—From the success attending applications of scientific research in military and industrial problems during the war, the lesson was drawn that our industries in peace-time should be infused with fresh and more vigorous life by methods which had proved their worth at our time of need. Foresight in these matters was necessary, since it behoved Great Britain, no longer with the industrial world at its feet, to make the utmost use of its resources, by adopting the methods that were most efficient and solidly based on science, in order to produce material that would maintain the tradition of the excellence of British goods. While it was recognised that the most powerful chemical industries maintained efficient research staffs, it was decided to encourage separate industries to organise themselves for the co-operative prosecution of research. To the associations erected under this scheme grants, for a term of years only, and usually on a pound-for-pound basis, are made from a fund of a million pounds voted by Parliament in order to demonstrate to the industries the advantage of investigating their own technical problems, for it was recognised that many industries would have to carry out research themselves before they could properly appreciate its application.

In its last published Report the Department remarks on the continuance of these grants to the associations beyond the originally intended period of five years, as this period has proved insufficiently long for the equipment of laboratories and the effective launching of important investigations, especially during a time of industrial depression.

A very wide field is covered by the research associations. Among those that have been set up in which chemistry is important are associations for the textile industries, for rubber, leather, and shale oil, for flour and sugar, for non-ferrous metals, cast iron, glass, refractories, and Portland cement, and for scientific instruments and the photographic industry.

As the results obtained by the associations are primarily for the benefit of their constituent members, the onlooker has a chance of gauging the chemical work carried on only from the communications which, following an enlightened policy, the management of some of them permits to be published; and as many of these are contributions to 'pure' chemistry, an example is afforded of the opportunity as well as of the necessity for work of this kind in the case of investigations undertaken primarily for an industrial purpose.

It would be impossible to review the work of the research associations for all these industries, even if the data were available, and so reference will be made only to some of their publications, including those of the

group which is concerned with the textile fibres, cotton, flax, wool, and silk, as the work published presents many interesting features. Thus there are being studied the products of the hydrolysis of cotton, with an obvious bearing on the constitution of cellulose, the chemical constituents of cotton waxes, and the action of micro-organisms on cotton fibres and fabrics. Flax, hemp, and ramie fibres are being investigated as to their distinguishing characteristics and behaviour with reagents that affect their lustre and absorption of dyes. Wool has been found to have a selective action, whereby it absorbs the alkali from the soap used in scouring, and methods have been evolved for accurately following the action in practice. Similarly with silk, a systematic study is being made of the action of acids and alkalies on the components of this fibre. In the respective laboratories the chemical and physical properties of each of these fibres are being studied and correlated for the purpose of explaining, for example, their strength and lustre, and at a recent meeting of the Faraday Society the methods and results of workers in all these fibres were reviewed in a General Discussion.

A close scientific scrutiny is being applied to the tanning of leather, and the chemical and physical changes involved, together with a bacteriological study of the process. Equally important for this industry and for that of making photographic plates is the study of gelatin, whose chemical and physical properties are being elucidated, while work of benefit to pure science has been published on the effect of light on the photographic plate.

The study of the chemistry of glass and the physical properties associated with changes in its composition is another example of work that has been reported in the literature for improvement of an industry.

The record, as has been stated, must be incomplete, but the subjects mentioned present the appearance of being valuable in the scientific study of material and process, and can scarcely fail to lead to the betterment of the respective industries.

Boards.—The Boards and Committees under the Department may be broadly divided into those which undertake the investigation of work of national importance, and those which undertake work of specific importance to Government Departments and correlate the scientific work that these carry out.

A large amount of chemical work is carried out by these Boards. The Departmental Research Boards and Committees dealing with chemical subjects are concerned with the cause of the deterioration of fabrics by organisms and light, and their fireproofing; with the changes that food undergoes under varying conditions of storage, and the constitution of fats; with the chemistry of the treatment of timber; with the survey of our coal resources and the economic usage of coal; with the production of alcohol and liquid fuel from waste vegetable matter; with the chemical aspects of the problems of adhesion, lubrication, restoration of museum exhibits; with building materials, paints, and the preservation of stone, and with the properties of several of the minor metals. For subjects of the magnitude and importance of some of these, staff and equipment have in several instances been provided on a considerable scale, and a growing number of monographs and communications to the literature issues from the respective Boards.

The Co-ordinating Board for Chemistry, like the similar Boards for other sciences, was founded for the purpose of securing interchange of information among Government technical establishments, seeing that outside interests are informed, when this is practicable, and arranging for researches not otherwise provided for. The Board carries out these duties in consultation with representatives of the Fighting Services and of other Government Departments materially affected, and with independent chemists, when departmental schemes of work are reviewed in the light of information that may be in the possession of any of the members of the Board. To this Board are referred questions of wider importance than are within the purview of any one Department, and it keeps under its consideration the development of the natural resources of the country. With further facilities for undertaking investigations, it will be in the position to extend such work and to arrange for subjects not otherwise provided for, as well as for those at present under investigation.

Assisted General Research.

Apart from the indirect help afforded to the universities by means of Government grants, direct assistance is given by the Department of Scientific and Industrial Research to research workers who may be students, or independent workers, and to important pieces of pure research. To these grants no conditions are attached ; they are given for the extension of knowledge.

One of the objects of these grants is to encourage the supply of highly trained scientific research workers to meet the growing needs of the Government, the industries of the country, and indeed of the Empire. The lack of such was felt acutely during the war, although now, for chemists with the usual qualification at any rate, the conditions have changed.

Students are given grants on the recommendation of their professor that they are a type likely to be greatly benefited by spending two years at research work after taking their degree. In this case the award is for promise and not for achievement, and the hope is entertained that the necessity for these grants will gradually disappear when university finance is on a sounder basis.

Grants are given to independent workers who have shown their capacity for research, and who are handicapped by lack of facilities which they may not be able to secure from private or other sources. Further, in the case of work of unusual importance, very substantial financial assistance may be given when it appears desirable.

In this way comes recognition of the national importance of the highest type of scientific work, and to this, of course, no conditions are imposed as to the lines on which it should be carried out.

Summary.

The State's appeal to chemistry has developed through the gradual recognition of the need for the application of that science to matters relating to its preservation, its currency, its financial support, its health, its food supply, its industries, and finally to academic science. A chart illustrating this development historically is appended to this address.

In the course of this development, advantage has been taken, if sometimes tardily, of the general advance in chemical knowledge, and frequent recourse has been had to the advice of well-known chemists of the day, and collectively of the Royal Society; thus for various purposes the following chemists, as officials or consultants, have in the past afforded assistance in the solution of specific problems referred to them, or by taking part in Commissions: Boyle, Newton, Davy, Faraday, Daniell, Graham, Hofmann, Redwood, Abel, Roberts-Austen, Percy, Dupré, Playfair, Frankland, Ramsay and Dewar. If has happened in several instances that as a result of these Commissions and references to chemists some definite chemical activity of the State has emerged.

It will be convenient in this summary to review the State's chemical activities before, during, and after the war.

Before the war.

Defence.—For its defence, establishments for the production of explosives were early maintained, and when this ultimately took the form of a chemical manufacture the Government factory took the lead in devising efficient processes, while from the various State research establishments has issued during the last fifty years an important body of original contributions to the theory of explosives and to the knowledge of their properties.

Metallurgy.—The metallurgical progress of the country has always been a concern of the State by reason of its application to defence by land and sea, and close touch has been maintained with successive developments in the manufacture and use of cast-iron, wrought-iron, steel and non-ferrous alloys. While the main advances in process have been made in the great iron and steel works, material contributions to knowledge in this sphere have been made by chemists in the Government service.

Revenue.—For its revenue, imposts were applied in early times, but with great uncertainty, until the charge was put on a scientific basis. Very accurate tables for the strength of alcohol were worked out under the supervision of the Royal Society at the end of the eighteenth century, to be superseded by revised ones issued only a few years ago, when, in addition, new tables were issued also by the Government Laboratory, for determining the gravity of worts before fermentation. The question of rendering alcohol unpotable, but still useful for industrial purposes, has occupied much attention. As some misapprehension still exists as to the availability of alcohol for industrial purposes, a statement has been incl ded in which the main facilities are indicated. It was on account of the necessity for safeguarding the revenue that the Government Laboratory was primarily erected, although it now performs chemical work for all State Departments.

Health.—The three main steps with regard to public health and sanitation in this period were the forcing of these questions into prominence by Playfair, with the consequent Commissions and legislation leading to the formation of the Local Government Board and its successor, the Ministry of Health, which has many varied activities in preserving purity of air and water and protecting the workman in dangerous trades; secondly, the determination of standards for a safe water supply by the pioneering work of Frankland; and thirdly, the appointment of public analysts by the local authorities, with the Government Laboratory as referee, for safeguarding the supply of food.

Agriculture.—Science was being applied to agriculture about the end of the eighteenth century, and at the beginning of the next Davy did pioneering chemical work for the Board of Agriculture. Private endeavour is responsible for the next development, State action being limited to the prevention of fraud in the sale of fertilisers and feeding stuffs. In 1909, however, the annual allocation of a sum of money to the Development Commission for the advancement of agriculture stimulated research in a large number of institutions engaged in the scientific study of problems in which chemistry plays an important part.

Other Activities.—In addition to the chemical work reviewed in the foregoing sections, there is a variety of subjects connected with State Departments to which chemists have contributed, such as the composition of the sea, and the composition and physical chemistry of rocks and building-stone. At the Government Laboratory a large number of investigations have been conducted on matters directly referred from Government Departments.

During the war.

In all the activities described, the war requisitioned the work of the chemist, but, naturally, predominantly to meet the demands of active warfare.

Defence.—The attention that had been bestowed on the subject of propellants enabled expansion to take place with no important alteration in the technique of their manufacture, to which was adapted a new type of cordite, ultimately made on the largest scale, without using an imported solvent. For high explosives we were in much worse case, as these had not been made by the Government, and were manufactured in Great Britain only in small quantity. Their study at Woolwich led to a rapid evolution of new processes, substances, and methods of use. Thus a method was worked out for the manufacture of trinitrotoluene, and to save this substance a new high explosive, amatol, devised. This explosive, consisting of ammonium nitrate and trinitrotoluene, passed exhaustive trials and was ultimately produced at the rate of 4,000 tons a week. The production of the ammonium nitrate for the mixture was in itself a stupendous undertaking, and the methods of filling the explosive into shell and other munitions gave rise to much ingenuity. In the Research Department, Woolwich, the number of qualified chemists engaged in the study of explosives in all their aspects ultimately exceeded a hundred, while for manufacture and inspection over a thousand were employed. The ideal set before himself by Lord Moulton in 1914, to produce nothing less than the maximum of

explosives of which the country was capable, was realised, and they assumed a quality and character that caused them to be copied by our Allies, and in reliability proved themselves superior to those of the enemy.

Starting unprepared, and without the advantage of a well-developed fine-chemical industry, we were able ultimately to make a reply in the field of chemical warfare that was rapidly becoming more and more effective; at the same time, by study and often self-sacrificing experiment, protecting the soldier by the development of very efficient respirators. In this connection and in that of explosives nearly every professor of chemistry in the country and many from beyond the sea were engaged.

Metallurgy.—The enormous demand for metals for munitions and countless other war requirements led to an unprecedented concentration of the metallurgical industries on the needs of the State, and to an equal concentration of metallurgical science on investigation devoted to improvement in quality of materials for new and special war purposes. The work of the Aircraft Production Department, aided by many metallurgists and engineers, on alloy steels, of the National Physical Laboratory on aluminium alloys, and of the Metallurgical Branch of the Research Department, Woolwich, on the heat-treatment of heavy forgings and on the drawing of brass, is typical of the successful effort made in every quarter. The knowledge thus gained was disseminated in the form of specifications, instructions, and reports, and has had a great and permanent effect on manufacture.

Health.—A committee of the Royal Society had been studying food values, and were able to afford the Food Controller, when he took office, valuable data bearing on the rationing of food. They had considered subjects which shortly became of much importance, such as a better recovery of flour in milling wheat. The chemical examination of the food for the Army in the war, carried out by the Government Laboratory, employed a large staff of chemists. For the supply of many fine-chemical substitutes used in medicine and surgery, formerly imported from abroad, such provisional arrangements had to be made as the organisation of a large number of university laboratories on a semi-manufacturing basis.

Agriculture.—Effects on agriculture during the war were shortage of the usual feeding stuffs for cattle and of fertilisers. The chemists stationed at Rothamsted gave special attention to the shortage of manures and prepared instructions for the guidance of farmers; and several sources of supply of potash were exploited, including kelp, felspar, and the flue-dust of furnaces. As sulphuric acid was required for explosive work, fine grinding of phosphates and basic slag was found to be more efficient than was expected. Shortage also directed the attention of chemists to the use of little-known food-stuffs, especially for cattle, and the information gained as to their feeding value was important.

Other Activities.—In many other activities in connection with the war chemists were directly involved, such as in affording advice on the conservation of materials, on the numerous questions arising from the operations of the War Trade Department, on the restriction of imports and exports, and on matters of contraband.

After the war.

The magnitude of the chemical effort, it can be claimed, was a factor in winning the war which must be reckoned as of importance only second to that of the bravery of our forces in the field. But it has left a lasting mark, and given to chemistry a value which, were it not for the rapidity with which the achievements of science are forgotten, ought to keep before the public its connection with almost every phase of activity.

Defence.—To take our subjects in the same order, we may consider some of the effects of the energy spent on the production of munitions. The intensive study of explosives and of other chemical substances used in the war has led to a more complete knowledge of their chemistry, their physical and explosive properties, and has advanced chemical theory. These advantages are not of military importance only, but are reflected in the production of trade explosives. The collected records of the Department of Explosives Supply afford examples of treatment of many problems of interest to the general chemical technologist, and not only to the explosives expert.

A further benefit was reaped by chemists in every position, from the Professor to the youngest graduate, coming into direct contact with manufacturing methods and thus gaining insight into the applications of their science. While it is true that the opportunity came to few of these to take part in the design of plant and primary choice of process, nevertheless the experience was a novel one, as it led them into the field of technology, and cannot fail to have widened their outlook. It became apparent that there was a shortage of a type of chemist which had been developed in Germany, skilled in the transference of the chemical process from the laboratory to the works scale in the largest enterprises. A chemist of this type is one who, besides having a sound knowledge of chemistry and physics, has had experience in the materials of construction used on the large scale and in the operation of the usual types of plant for carrying out the operations of chemical manufacture, and who is capable of working out flow-sheets illustrating the process, and operating plant with every regard to economy. The need for instruction in such subjects had been borne in on men like the late Lord Moulton, and as a direct result of the war-time experience of our deficiencies in this direction has arisen the movement for erecting Chairs of Chemical Engineering in some of our universities. It is to be expected that from these schools, especially where the instruction is superimposed upon a full graduate course, will emanate men who will lead the way in the application of academic science to industry.

Metallurgy.—While the interest of metallurgical science in war material has fortunately fallen to a peace-time level, State participation in the support of scientific research remains far greater than before the war. In metallurgy it is exercised through the Department of Scientific and Industrial Research, with its organisations of the National Physical Laboratory and the Industrial Research Associations, as, for example, those dealing with the non-ferrous metals and with cast-iron. The State also continues to maintain efficient research establishments for the Fighting Services, but it is significant that the largest of these is undertaking industrial metallurgical research on a considerable scale, for the benefit of the

brass and other industries. State support and encouragement are undoubtedly powerful factors in the rapid progress now taking place in every branch of metallurgical science in this country, and there is scarcely any related industry which can fail to benefit.

Revenue.—Since the war the principal matters affecting the revenue are the higher duties, which have rendered necessary a further denaturation of alcohol. Improved facilities have been granted for the use of alcohol for scientific purposes and in industry; regulations have been formulated for the use of power alcohol, and duties have been established on imported fine chemicals and synthetic dyestuffs.

Health.—The food shortage during the war called attention to the nature and quantity of our food supplies, and led to further investigations being undertaken by the Department of Scientific and Industrial Research on food preservation and storage. Activity is also shown by the appointment of Committees which are working on the subject of preservatives and colouring matter in food, and on the pollution of rivers by sewage and trade effluents. A great field is open in the co-operation of chemistry with medicine in the discovery of substances suitable for the treatment of the numerous diseases now traced to parasites in the blood.

Agriculture.—So far as fertilisers are concerned, the lack of a supply of fixed nitrogen from the air which obtained throughout the war has now been rectified, and Great Britain for the first time is no longer exceptional among the nations by neglecting to provide itself with synthetic ammonia for agriculture and for munitions. Such war-time expedients as the use of nitre-cake instead of sulphuric acid for making ammonium sulphate and superphosphate and the recovery of potash from flue-dust have not survived, but there has been a gain in the further development of 'synthetic farmyard manure' and the increased use of basic slag. The present activity in research in agricultural chemistry of a fundamental character is leading to a better understanding of problems of the soil and of plant and animal nutrition, and cannot fail to be of ultimate benefit to farming.

Organised Applied Research and Assisted General Research.—Established during the war as a result of an appreciation of the contrast between the successful application of scientific method to military purposes and the want of such application to many of our manufactures, the Department of Scientific and Industrial Research has extended over a wide field. Its main activities have been sketched in the directions of State encouragement to industry to apply chemistry to its problems, of State investigation of vital problems beyond the sphere of private enterprise, and of assistance to workers in the purely academic field. In all these spheres activity is shown by the contributions to knowledge already forthcoming.

In the expansion that has occurred in the chemical sections of State Departments since the war, it is interesting to note the increase in the number of chemists that are employed. As far as can be gathered, the number of chemists working in departments maintained wholly by the State is 375 for the present year, compared with 150 in 1912, while in

establishments to which the State affords partial support, such as those under the Development Commission and the Research Associations, the corresponding numbers are 150 and 50. In addition, grants are made to 145 research students and to 11 independent research workers, involving a yearly sum of about £50,000.

From the foregoing account of the connection of the Departments of State in the United Kingdom with chemistry, it is possible to trace a gradual development and ultimately a change in attitude, in passing through the stages of compulsion, expediency, and assistance.

From motives of security the State was compelled to give heed to chemical matters involved in its defence, such as those which appertained to munitions of war, including metals used in their manufacture; it was constrained to uphold the standard of its currency; and it was obliged to secure a revenue. As a consequence, the first chemical departments were set up in connection with these activities, and from them have emanated notable additions to chemical knowledge, improvements in methods of manufacture, and specifications for Government requirements that have led to improved material becoming available for civilian use. Although mostly conducted with inadequate staff, the study of these questions, it can be claimed, proved of national advantage when the time of need arose.

In the next stage, the public conscience having been awakened by the pioneering work of Playfair, it appeared expedient to safeguard health by attention to sanitation, and, as the quality of food was unsatisfactory, to set up a chemical control. Although a start was made by Davy, a member of the then Board of Agriculture, progress in this subject passed to private enterprise, and a century elapsed before direct assistance was afforded to this important matter. Out of these activities come our present system of supervision over the purity of air, water, and food, and also the recent progress made in the application of chemistry and physics to problems of the soil.

The last and more recent stage is in the nature of a recognition that the State is under an obligation to assist science, and in this case the science of chemistry, on which so many important industries are based. It took the war to bring home the danger that, although the record of the country as regards discovery in pure science was unrivalled, its systematic application was too often left to other countries, with the result of lamentable shortages during war and the risk of many industries being ineffective in peace. A measure of Government intervention and action appeared requisite, and research became the business of a Government Department. Outside of the great firms which maintain progressive chemical staffs, the firms in numerous industries have been encouraged and assisted to co-operate in the betterment of their manufactures by the application of the methods of science, and from these associations and the organisations dealing with national problems begins to flow a stream of communications indicative of useful work accomplished. Nor is the foundation of it all neglected, for encouragement is given to workers in the academic field to follow out their ideas, whithersoever they may lead them, in accordance with the truth that ‘ research in applied science might lead to reforms, but research in pure science leads to revolutions.’

It is important to be able to record an advance in securing an interchange of information among Government Departments, and between their work and that of the universities, a matter which before the war was unsatisfactory, as it was mainly personal and sporadic.

And it is a hopeful sign also that, although the knowledge and appreciation of the methods and capabilities of science are still generally wanting, there have been of late signs that these matters are coming to engage the attention of those who guide the policy of the State.

SECTION C.—GEOLOGY.

Note to Address on following pages, by the President of the Section.—It was hoped that this Section would have been presided over by Dr, C. W. Andrews. He had indeed accepted the invitation of the Council to become President, but the state of his health later compelled him to resign. His untimely death has deprived our science of a widely-travelled and most talented geologist, and a vertebrate palæontologist of world-wide distinction.

SECTION C.—GEOLOGY.

GEOLOGY IN THE SERVICE OF MAN.

ADDRESS BY

PROFESSOR W. W. WATTS, Sc.D., M.Sc., LL.D., V.P.G.S., F.R.S.,

PRESIDENT OF THE SECTION.

Introduction.

Although Geology in the modern restricted sense of the word is over a century old, and possesses a flourishing family of descendant sciences, it is still possible to trace its immediate parentage and ancestry. The only begetter is unquestionably the mining industry, and it is to the ample exposure of rocks in mines, their condition and arrangement in the simpler mining districts, and the necessity for accurate knowledge of these districts with regard to composition, succession, and arrangement, that we owe the earliest detailed knowledge of the earth-crust in certain restricted localities.

The other parent was of more advanced years, and may be described as 'insatiate curiosity': the natural instinct for observing and collecting odd and bizarre 'rarities' found in excavations or seen in natural rock exposures. These fossils, using the word as then employed and not in the restricted sense now usual, naturally kindled interest by reason of their natural beauty, their regularity in shape, their properties, their likeness to, and yet their tantalising difference from, the appearance of living animals and plants. It was tempting to draw inferences from their occurrence and to explain them either by marvellous operations which fuller understanding of Nature had not then inhibited, or by means of catastrophic events like those familiar in the Mosaic cosmogony.

Although much had been observed and thought out by his predecessors, it is to Werner that we owe the most successful generalisations in a mineral-bearing district; generalisations which gained a wide influence owing to the enthusiasm and eloquence that attracted students from all over the world and imbued them with the desire to confirm and spread the Master's ideas. To Werner also is due a reaction from the fanciful speculations of preceding periods, with which he was so impatient that he proposed to drop the very term Geology and to substitute his own word 'Geognosy' for it, a word intended by him to separate the knowable from the unknown.

Probably there would have been less controversy between Neptunists and Plutonists had Werner committed more of his work to writing, and not left us dependent on his pupils for their versions of his views. But it is a curious fact, and one probably not dissociated from a geologist's devotion to field study, that many of those who have made great advances have either disliked the act of writing or have been unfortunate in the style of their written work. It will be sufficient to couple with Werner in this respect such names as William Smith, Sedgwick, and even Hutton, not to mention those of more recent geologists. It has not been from Smith alone that views and conclusions have had to be extracted, almost by force, and committed to writing by faithful devotees.

Yet, after all, this failing has not been without its advantages. The joy of such men is in discovery, and they are happy and contented when, but only when, they feel perfect confidence in their conclusions. If their results then get published it is with an authority and finality denied to lesser men. In the progress of their work they are apt, as in fact all of them did, to infect their friends and students with the enthusiasm that only the spoken word can arouse. And to others they have always been most generous, even lavish, in giving ideas and momentum, partly out of sheer good-nature, but much more through the desire to watch the germination of the good seed that they sow broadcast and to see the harvest reaped, not by or for themselves, but for the advantage of the science whose welfare is their chief care.

During the early growth of the science, as in human families, it was the influence of the other parent that was most felt. From the earliest thinkers of Greece and Rome we have record of numberless observations and discoveries, sometimes in respect of minerals or organic fossils, sometimes of unusual phenomena in mountains or volcanoes or in the relations of sea and land, generally leading to reasoned conclusions, many of them perhaps fanciful, some even absurd, but others so sound and far-seeing that they have not been upset at the present day. Many other countries, joining the favoured ones along the Mediterranean, carried the torch forward, and, in spite of the clogging influence of the vested intellectual interests of the day, the stock of knowledge gradually grew, until we find that Leonardo da Vinci was able to make as great an advance in the knowledge of the earth as he did in his own arts of painting, sculpture, and architecture.

It is true that during this period observers had a tendency to confine themselves too exclusively to one or other side of their subject, and were in the habit of reproaching one another with neglect of neighbouring branches, but even this made for progress by stimulating competition and discussion.

In spite, however, of all that had gone before, in the fields both of fact-collecting and of speculation, it will be admitted that no single man made so great an individual advance, or placed it upon such an enduring foundation, or did so much on which the future of his science was to depend, as William Smith. And it is noteworthy that the spur to his discoveries was not so much his theoretical views or even his scientific zeal, as a plain and practical issue—the finding of a short-cut to speedy and accurate land valuation.

The discovery by the ‘ Father of English Geology ’ that fossils are the ‘ medals of creation ’ and that strata are each characterised by special suites of organisms was certainly one of the greatest ever made in the history of geology, and upon it have been founded directly or indirectly almost all the later advances in the science. But for the fuller utilisation of his discoveries there were needed the artistic faculty and a wide knowledge of places and people, both of which he fortunately possessed. Thus he was able to introduce handy, crisp, easily remembered and pleasantly sounding local terms to characterise his ‘ Formations,’ and to represent the outcrop of strata on maps which were not merely topographical but, for the first time, were tectonic also. So well did he discharge this latter function that a comparison of his general map of England with the latest production

of the Geological Survey on a scale at all comparable with it fills one with astonishment at the amount of work accomplished by him, single-handed, and with admiration for his accuracy.

It is strange that, in the amateur and official work which followed during much of the nineteenth century, so little interest was taken in the industrial application of geological knowledge which in Smith's hands had been so productive. The science had, as has been said, the 'landed manner,' and the dignity of its application to arts and industries was little appreciated. A former Director of the Geological Survey of Great Britain, Sir Andrew Ramsay, quoted with approval the saying of one of his colleagues, 'it is but the overflowings of science that enter into and animate industry.' And thus, though the scientific side of geology stood to gain much otherwise unattainable information from contact with its economic application, this source of knowledge was not fully utilised, and an air of mutual suspicion—not wholly unjustified—grew up between 'theoretical' geologists and those who applied geology to mining and other economic problems. Fortunately this feeling is passing away; the two sides have found that each is indispensable to the other, and geologists are everywhere co-operating with those whose work is connected with the discovery or exploitation of the mineral wealth of the earth-crust.

Material Service.

Coal.—The first branch of industry to which geology made itself indispensable was coal-mining. Geology has long been in close contact with its problems, in mapping the extent of coal-fields, collecting information as to the succession of measures and the existence and lie among them of wants, faults, and igneous rocks, tracing the extension and variation of coal-seams, and estimating the resources available; and, as seams are worked at increasing depths, and in those parts of fields concealed under thick unconformable cover of more recent formations, the work of the geologist has become more essential and increasingly productive.

It is interesting to observe the application of the 'academic' sides of geology to these more recondite problems, in unravelling tectonic complexes, in the collection of facts which may eventually elucidate the precise conditions under which different varieties of coal have originated, in applying knowledge as to the limits of the original areas of coal deposit, in the interpretation of stratification in the light of the progressive travel of coal-forming conditions geographically across the coal-producing areas, and in the stratigraphical relationship and exact mode of formation of the covering rock-systems.

It is true that the accessibility of coals when first exploited, and their distribution in seams of varying quality, led, and in the newer areas are still leading, to much waste: waste on fruitless search in the light of obtainable knowledge, in exploitation of good, thick, and easily worked seams to the neglect of poorer ones, in the non-preservation of satisfactory plans and the consequent leaving of derelict areas, in unsatisfactory drainage, and in the loss of valuable by-products. But there is a corresponding advantage to those of our generation that some exposed areas of complicated structure and many of the concealed coal-fields were left for ourselves and future generations by reason of working difficulties which it would have been premature to face in the time of easily obtained abundance.

Even to-day, in spite of improved technical knowledge, there remain many areas in which information and inference are both scanty, and where difficulties met in working have not yet been surmounted, while there will be in the future ample scope for improved methods and inventions to deal with coal at greater depths than those at which it can at present be economically worked. There is room for much new and more precise study than has yet been devoted to the variation of coal-seams, both in the vertical direction and when traced over the wide areas of their extent. Elaborate and knowledgeable sampling, followed by new means of testing, and these again by new methods for recognition of varieties, have still to be put into practice before it can be said that we are making a justifiable and economic use of the capital reserves stored up in the rocks.

Oil.—While we blame our forefathers for their destructive and wasteful handling of the coal-fields, it is ourselves and our own generation that we must blame for serious waste of oil and the destructive exploitation of oil-fields that have been permitted. There is no economic subject to which geology has so direct a relation as the occurrence and exploration of oil-fields, and nothing in recent times has given so much employment and such valuable experience to geologists all over the world. It is the only example we have of the sudden introduction of a new source of fuel on a large scale in a late stage of industrial development, and it has already revolutionised many branches of engineering practice. The introduction and spread of the internal-combustion engine and all that this implies in space-economy, cleanliness, labour-saving, and comfort, has been the greatest engineering feature of the late nineteenth and early twentieth centuries, and it has given rise to systems and methods which mankind would be loth to abandon. The whole world is being searched to prolong the good times that we live in ; but in spite of the fact that there probably still remains a recoverable percentage in the oil-producing areas, and that there must be new fields awaiting discovery, there are already signs that the high oil-mark has been reached if not passed. But, again, it is no small comfort that although our supply of native oil, easily won and easily refined and applied, cannot last very much longer, there are abundant supplies of oil-shale still left, sufficient to take its place for very many decades to come.

Metals, &c.—Although the greater part of to-day's session is to be taken up by papers and discussions on special sides of economic geology, by those who are far more competent than I to speak on them, I cannot resist the temptation to say a few words on that side of the subject which touches on metal-mining. There is probably no subject which has been in the past more dominated by the 'practical man,' who may be defined as the most theoretical of all men, but whose theories are seldom proved and are often not susceptible of proof. The valuable information that was accessible to him has been wasted because he could not use it to the best advantage, or else it has been lost because he could or would not impart it. On the other hand, the 'theorist,' as he has been contemptuously named, has been hampered because he has often only been called in when difficulties were excessive and when the train of facts or reasoning which would have been so valuable to him has been lost.

In Britain the mining industry is so old and the mineral wealth in certain spots was so plenteous and accessible that the metal-mining geologist has had little chance. The eyes have been picked out of the

mines long ago, and in certain cases their very bones picked clean, and the country has been left in such a condition that its original state can only be guessed at, and problems of relationship, structure, and origin are past solution. Consequently it is in the countries which have not been inhabited by successive races of highly civilised peoples, or in relation to substances for which there was in the past little or no demand, that the subject has been susceptible of real advance.

Thus it is that such strides in mining geology have been made in Canada, the United States, India, South Africa, and Australia, where there has been a fair field to work upon, and where preliminary surveys have opened up the country and given an idea of its hidden resources. In no other areas of the world has the work of official surveys been watched more carefully by men of capital and enterprise, and money has rarely been lacking for development where there seem to be prospects of a fair return for it. Fortunately, too, the training of official geological surveyors has provided a type of geologist exceptionally well fitted both to prospect independently and to follow out in minute detail, and from a different view-point, the preliminary and less detailed examination which is all that is practicable in an official survey. These men have carried with them not merely competence and enthusiasm, but a thorough belief in scientific principles, an extensive knowledge of border-line sciences, and the ability to apply both principles and methods to the problems involved. In the hands of such men the surest guides are scientific principles, just as in the hands of those with 'a little learning' imperfectly understood principles are most dangerous; and as the search for ores becomes keener, and as deposits smaller and more tenuous become worth working, the need for increased knowledge of principle and for minute detail in observation steadily grows.

Fortunately, we have not yet exhausted the existing stores of highly concentrated and singularly pure ores, salines, refractories, &c., and the need is less acute than it will eventually become for much-improved methods of concentration and purification. When we feel the pinch it will be necessary to call upon the chemist to endeavour to make available the abundant supplies of less pure and less concentrated materials which will remain over for our successors when we have picked out the best. This has already been to some extent effected for oil and it is beginning for coal; it must eventually be done for the still less pure sources of these two substances, for less concentrated ores and the like.

Stone, &c.—The geologist has already done much in the investigation of the qualities of building-stones, plastic substances, and the materials for roofing and cement. To a large extent the materials in use are satisfactory in the air and surroundings in which they occur in Nature. But the added problems of a town atmosphere, accompanied by increased stresses in large buildings and the modern demands of the architect and sculptor, have still to be met, if our buildings are to be more permanent and our towns to present a less weather-beaten aspect than they now do. New and reliable means of testing are required, and we need a more thorough understanding of the reactions produced by impure atmospheres, and the effects of the presence or absence of protective or destructive organisms. Future investigation will react in the production of more satisfactory preservatives, and it may lead to increased production and

adoption of artificial stones devoid of the qualities which undermine the power of resistance of natural stones ; at the same time more control over colour and shaping may be obtained.

Roads.—Closely akin to the subject of building materials comes that of stones used for flagging, paving, and metalling of roads, to the provision and study of which the geologist has already very largely contributed. New problems are daily introduced as road traffic becomes heavier and as roads are required to be freer from dust and vibration. Already many waste products have come into valuable utilisation, and a wide range of road metals which can be called upon for these purposes exists in almost every country.

In the siting of roads, railways, and canals, however, geology could render much more useful service than it has yet been called upon to give. The routes that are cheapest to make are by no means the cheapest to maintain, and the geological survey of routes would very often suggest slight deviations which would be more economical in the end than when the shortest route compatible with the gradients is taken.

The princes of road-makers in the old world, the Romans, were perhaps too heroic in their dealing with gradients, but they exercised quite remarkable skill in choosing such directions as to secure the least formidable slopes consistent with the general design of their routes. Their roads were, however, constructed primarily for strategic purposes and secondarily for transport, and it was necessary to sacrifice something. On the other hand, the constructors of the coach-roads were, perhaps, too sensitive to the psychology of their horses and the limitations of their vehicles, and their roads are not ideal for present-day traffic. Some compromise seems to be required between the two methods, and not the method of the Roman tempered by the cuttings and tunnels of the railway engineer. Now that we have a vehicle that rejoices in a hill, whether for or against it, and for the first time have a means for hill-climbing at speed, it is a pity to flatten down gradients too much ; and though it is legitimate and even necessary to remove dangerous crossings and curves, it should be remembered that an everlasting straight vista is as exasperating to a driver as it is heart-breaking to a horse. And if roads of this most desirable type are to be satisfactorily and cheaply maintained, it will be more than ever necessary to study routes in relation to the rocks that are traversed and the water contained in them.

Something of what has been said with reference to roads applies with equal force to other engineering undertakings, railways and canals, harbour-works, bridges, and large and heavy buildings, particularly those intended to stand for centuries. The general success of such works is ample testimony to the knowledge and skill expended upon them by engineers and architects, as well as to the elastic toleration of sites so heavily taxed ; and one is tempted to believe that a much larger amount of study has been given to geological questions in these cases than is usually admitted.

Water.—Of all engineering questions, that most closely involved with geological science is probably water-supply. So far as underground water is concerned, geologists and engineers working together have amassed a volume of fact and principle which has not yet been completely codified and rendered accessible. An unexpectedly large proportion of

the available rainfall has in many instances been obtained by successful drilling, in spite of the complication of the question by surface pollution, and in the face of many legal inanities and much charlatanry. And the extension of these methods to arid regions, as in Australia and North Africa, has brought under cultivation large areas which needed nothing but the 'striking of the rock by the rod' of the driller to make new oases in the desert, and thus render available some of the richest soils in the world.

Much the same is true of overground supplies, which have been a blessing not merely in the towns and lands supplied, but to the rivers and drainage basins regularised and protected in large measure from ever-recurrent floods and the damage consequent upon them. Although in such works geological conditions are often taken into full account, an elaborate geological survey at a very early stage would in most cases more than pay its way. Such a survey would not only give a good preliminary idea of the nature and tectonics of the rocks underlying sites of dams and reservoirs, but it would save its cost in limiting the number and in giving rational direction to the inevitable pits which must be sunk, by restricting them to the elucidation of points which the surface mapping leaves obscure. It would at the same time direct attention to the innumerable pitfalls which sites often present and would generally provide on the spot much of the requisite material for construction.

It is an arguable question whether the expenditure of such vast sums as have been devoted to the supply of large towns is entirely justified. The provision of a single supply of which large quantities are used for drinking, cooking, and industrial purposes, necessitates that the water shall be of immaculate purity, and this pure substance, the purest of all the things we consume, is employed—may we not say wasted?—for flushing, washing, and a host of other purposes for which a less pure water would suffice. Surely the time has come when people could be educated up to the use of a dual supply, and this should be a commercial possibility where the area served and quantity used are really large. The experience of London has shown the very high cost of a single supply to all consumers and for all purposes, and the limits of future supply are almost in sight. It seems to be time that the problems of a dual service should engage serious attention.

Power.—Owing to the configuration and rainfall of the British Isles, and their congested population, we are apt to think of water questions in terms of supply, and, though we are using a certain amount of water for power, there is only a limited development possible. In many other parts of the Empire, however, this is becoming a valuable asset, and nowhere more than in Canada, which is rapidly developing its resources on a very large scale. What has been said with reference to water-supply is of equal application here, for the physiographic conditions which bring about steep gradients, accompanied by large bodies of water, introduce factors of denudation, transport, and deposition by the water which call for most careful selection of sites for reservoirs and works, if the all too frequent disasters are to be avoided, and if the schemes are not to be ephemeral in duration and excessively costly in upkeep.

With sources of power other than coal and water—including that of the tides—the geologist has little concern. But there has been brought

into service, at Volterra in Italy, a new source of power in the high-temperature steam from fumaroles which had previously been used only as a source of borax. Now the steam is being tapped by borings adventurously carried out, and its chief heat is employed in running great power stations, only the residual heat being given up to the manufacture of borax. This may be but the beginning of the application of a new and valuable source of power in which the services of geology will be required and from which that science stands to learn much. We are haunted by the fear that a limit will be imposed by high temperature to deep mining, while that very heat may provide energy as valuable as the material which would otherwise be mined; just as we dread the gas from certain coal seams when the gas might, if it could be exploited, give a return equivalent to that of the coal itself.

Agriculture and Forestry.—Leaving aside relations already touched upon, the connexion of geology with agriculture and forestry is through the medium of soils and subsoils, and, though the geologist seems unsuited to deal unaided with soils, his methods are those which the soil investigator must use; and soil surveys are now being carried out by agriculturists working in conjunction with geologists. This results in giving new and valuable facts and inferences for the benefit of both sciences. On the geological side it is rendering more available the facts of plant distribution, and what has been called *agronomics*, which, speaking for myself, I have always found very hard to get hold of. On the other hand, the services of geologists are likely to be of especial value in the matter of transported soils, loams, loess, brick-earths, drifts, gravels, and the like, where the conditions of formation may in many cases provide a key to their peculiarities. The same considerations apply to forestry, and here in addition well-established facts, such as the successive forest types displayed in peat-bogs, may betray principles that will be of service in practice. Questions of site, sewage disposal, and health are bound up with questions of water and agriculture and need no further notice here.

Military Science.—It will be readily admitted that geology has been of conspicuous service in connexion with military operations in such ways as the siting of camps, trenches, and dug-outs; while the minute study of the water-table in northern France during the late war was not only of value in obtaining water supplies but was of conspicuous utility in mining and counter-mining, in which exact and detailed knowledge was successfully pitted against a knowledge which was 'just there or thereabouts.'

The 'eye for a country,' the visualising of features plotted on maps and making the utmost use of them, qualities on which good strategy is founded, are the same qualities which are essential to a competent geological surveyor; and I cannot help thinking that strategic ability would reap as much advantage from a knowledge of the underlying canons of topographic relief as the geologist would from a study of the principles of military topography. It was a wise scheme to train the British Home and Overseas armies on ground similar in kind and in relief to that on which they were about to fight in France; but it should have been realised that physical causes and the resultant topographical relief differ in essential particulars in temperate and tropical climates.

Innumerable as are the services which the science of geology has rendered to man on the material side, these are at least equalled, if not outweighed, by those rendered on the intellectual side, either in the direct application of its principles to the life of mankind, or in the aid given to other sciences and the confidence engendered in such of their conclusions as can be tested in the light of geological history.

Throughout most of its range and in its more special directions, geology, like zoology and botany, is mainly an observational science. Multitudes of facts have to be observed and grouped, and as much skill is required in selecting from them the more significant and decisive as in collecting them. Experiment for the most part is of service in the criticism and verification of tentative theories; and, on the physical and applied sides more especially, it is becoming of great value. But the process of examination-in-chief, and the cross-examination in the field by a highly qualified and fully trained observer, are so exhaustive that not very much is left to submit for checking to the experimenter.

Even more than either of these two sciences is geology an open-air science, and one which calls for and imparts a love of Nature, that cannot but deepen as knowledge increases. Its most interesting work lies as a rule in the districts most attractive for other reasons. In the course of geological work the country must be thoroughly traversed, and, when possible, should be seen again and again, in all lights, under all aspects, and at all times and seasons. Hypotheses grow but slowly, and call for constant checking or verification in the field, the gradually growing ideas being an intensive spur in the collection of new facts or the re-observation of old ones, and in the comparison with like or unlike cases published or unpublished. But, as they grow, hypotheses give to their framer a power of prediction, more precise as the hypothesis is better founded; and one of the most fascinating parts of his work is the testing out of such predictions and the making of crucial observations thus needed and inspired. It is for these reasons principally that geology has earned its reputation as a fighting science. It is hard to decide just exactly when evidence amounts to absolute proof; and different observers, having reached varying stages in the completeness of their observations, may be led by the sum of them to different explanatory theories; or in the sphere of their own work they may be specially influenced by facts current there.

This seems to be the place to enter a protest against dominant ideas with regard to education and training in geology. The tendency in early education has been to squeeze out other sciences in favour of those that are called fundamental, and to suppose that, because it makes use of most other sciences, training in geology ought not to be begun until all others have been mastered. This is to go counter to the history of the science itself. Its leading methods were evolved in the early days of physics and chemistry and by men often ignorant even of such principles as were then understood. As geology has grown it has given to these sciences many problems for solution in return for the solutions received, problems which would have long waited for attention had not their geological application been urgent. Further, as the solution of his problems requires not only a very extensive knowledge but a workmanlike ability to apply both methods and principles, it is difficult to say at what

stage even the most competent scientific man, if he is ultimately to deal with all his problems himself, can be ready to begin the study of geology.

Meantime, qualities of far higher value to a geologist, which in most cases can only be acquired young, are being lost, such as the habit of close observation, the aptitude to distinguish minute resemblances and differences, and the faculty of judging tendencies, together with the instinct and patience to make collections. These propensities come very early and speedily become blunted if not exercised. I would advocate, with all the earnestness of an old teacher, that some form of earth-knowledge involving observation of facts and collection of specimens, and the drawing of inferences from them, should find a place in schools and be encouraged at the Universities side by side with the fundamental sciences. Such studies will not possess the meticulous exactitude of the others, but in this respect their tendency may be corrected by them. They will, however, bring the student into contact with realities, things as they are, instead of inaccessible, abstract conceptions, things beyond experience—such as *pure* substances, or forces acting in the absence of *friction*. They will give him the thrill of discovery and explanation, teach him that the end of science is to extract law and principle from observation and experiment, and, instead of keeping him along rigid lines to an assured and pre-obtained solution, will give him a choice of approach and accustom him to frame and test hypotheses which to him at any rate will be new and his own. Further, they will do much to teach him his own shortcomings and give him a keen incentive to acquire the very sciences which in themselves may be dull or even repulsive until he has convinced himself of their utility and necessity to his own work.

While acknowledging indebtedness to those sciences which have so generously contributed their results to geology, we feel that we have some ground for complaint that at times their votaries have not resisted the temptation to drop bombs which have exploded in our midst and produced a certain amount of trepidation and sometimes legitimate indignation. We consider that it is up to those who feel compelled to do this to acquire some knowledge of geological principles and of the lines of reasoning on which they are founded. They should recognise that a pyramid is difficult to upset, because in the process of building it the materials and structure have been carefully selected and tested by the builders. To be told after a century's search and reasoning that we must take our time bill and 'sit down quickly and write' off 80 or it may be 90 per cent. of it, ought not to have disturbed us as much as it did, not more indeed than now does the permission of the representatives of the same science to multiply our original time bill, if we like, by ten or twenty, or even more, so far as their present state of knowledge extends. Our answer is that we have not done the one and have no desire to do the other, so far as the sedimentary rocks at present known to us are concerned.

The geologist, however, should be, and is, the last to deprecate the application of the highest and newest conclusions of physical and chemical science to his own problems and to the criticism of his solutions of them, for it is certain that this will always result in doing much to reduce many of the barriers which retard his advance. For this reason we must welcome even so fantastic a hypothesis as that of Wegener, for the problem of the overthrust 'nappes' of mountain regions is one of our greatest

difficulties, and all explanations hitherto proposed are so hopelessly inadequate that we have sometimes felt compelled to doubt whether the facts really are as stated. But the phenomena have now been observed so carefully and in so many different districts that any real doubt as to the facts is out of the question, and we must still look for some adequate method by which the overthrusting could have been brought about. And if dozens of square miles of ground have been shifted over their foundations and away from their roots for many linear miles in the course of a single geological Period, who shall say what might not be accomplished in the course of Eras ?

Important consequences flow from the fact that the goal and expression of most geological research is the construction of a map of the area studied. To the layman who studies a country with a geological map in hand, it is hard to resist the conclusion that the map is merely fanciful ; he can see no evidence for the lines laid down or the symbols employed, and he is astonished when trenching or drilling proves their correctness at any particular point. It is difficult for him to see or to realise the cumulative force of the aggregation of minute pieces of evidence, slight differences in slope or soil, variations in quality, quantity, or luxuriance of vegetation, variations in dryness or moisture, the distribution of culture, the extension into the area of some underlying tectonic plan—the laws of which may have been worked out elsewhere—and the thousand-and-one considerations which go to make up the mind of the geologist.

It is, of course, perfectly true that the individuality of the surveyor enters not a little into the extrapolation of geological lines beyond the points where direct observation of the rocks is possible. So much is this the case, that it is feasible, from the inspection of his map, to gauge, not only the geological competence, experience, and attainments of the surveyor, but his knowledge and grasp of physiographic form, his power to see into intricate solid geometry, his artistic skill of hand and eye, and, above all, that indefinable quality, his 'eye for a country,' on which so very much depends.

The construction of a map has the further advantage that it grows by the alternation of periods of observation in the field with periods devoted to the thinking out of structure after each day's work and in the intervals between successive visits to the field, so that, with every return to the ground, the facts may be re-observed and lines re-tested in the light of growing knowledge. It is true that ideal observation should be so complete and exact that re-observation has nothing to teach ; but, as a matter of fact, with a map as with a book, what one takes from it is what one brings to it, clarified, improved, and extended. There should be allowed to professional geological surveyors as much elasticity as possible, so that, in addition to detailed and exhaustive primary survey, there may be frequent revision in the light of their own work and that of their neighbours. In this respect the hand-coloured form in which geological maps were originally published has an advantage over the newer, cheaper, and more consistent colour-printed maps.

Geologists should give a cordial welcome to the new aid provided by aerial survey and photography. This provides the last point of view of their areas which has been hitherto denied, though they have been in the habit of making use of the only substitute open to them, prospecting

and photographing from the highest points accessible. Many unexpected results have thus been secured in archæology, and at least as much may be looked for in geological surveys even in settled and surveyed districts, while in unsurveyed and unprospected regions its use is proving of the highest importance. Too much credit cannot be given to Canada for its enterprise in using this method for the prospecting and preliminary survey of the animal, vegetable, and mineral resources of its great hinterland by means of the aeroplane. A great saving in time and cost has thus been secured, and the method bids fair to remove the reproach levelled at the British Empire that such vast areas of it are practically unknown.

Physiography and Geography.—It is because of the variety and intensity of observation essential to geological surveying—in the course of which every acre of his ground must be traversed, and much of it re-traversed—that the geologist must necessarily become a physiographer and geographer. There is a limit to the perfection of topographic maps and surveys, even when, as in the United States, there is close co-operation between the Topographic and the Geological Surveys; and it is the duty of the geologist to take note of innumerable features which have no delineation, still less explanation, on such maps. The geologist is probably the only class of person who has to traverse large areas with his eyes open not to one class of phenomena only, but to all that can help him to decide questions of concealed structure; and he naturally seeks to supplement this by personal contact with the inhabitants, and with their written and unwritten records, which it is part of his business to interpret and explain. Nor can be confine himself to the purely physiographic aspect of his area. He is led into bypaths as a by-play, and many facts with regard to the distribution of animals and plants, and of the dwellings, occupations, and characteristics of the people, can scarcely escape his observation; neither can he shut his eyes to historic and prehistoric facts. Thus, when a geologist leaves his district, he is generally possessed of a store of knowledge reaching far beyond the strict bounds of his science.

While geologists, from the conditions under which they work, have been able personally to make individual contributions to these sciences, the most important service of geology as a whole has been the transformation of geography from a static into a dynamic science. In its earlier stages, geology discovered that progress involved the close study of the earth of the present and the application of that knowledge to explain its past changes; and the progress of geology has only intensified both the need of deeper study and the fuller application of it. To-day it is essential for geographers to be perfectly familiar with the past history of the earth in order that they may be able to explain the phenomena of the present.

The question may be summed up by saying that geology has become a physiological study of the earth as an organism with a life all its own. We can watch the geographical changes through which the earth has passed, revealed as they are in the nature and distribution of rocks and fossils. We can even discover the dry land—the actual landscape and physiographic relief itself—preserved in a fossil state, and judge from it the climates then prevailing and their distribution in distant epochs. We can form some idea of the modes of origin and dates of appearance of continents

and mountain chains, and other leading features of the relief of the crust. We are learning to read the evidence given by the interactions of igneous and aqueous rocks as to the nature of the stresses by which the structure of the crust itself has been moulded. There are, it is true, many gaps in our knowledge, but their very existence is of value in quickening and directing research in order that our history may become as full as it can possibly be made. Each advance upon the technical side of the subject, the pursuit of detailed zonal stratigraphy, the application of the microscope in so many new directions, and the broadening of the area of study, all react sooner or later in improving, refining, and extending our knowledge of earth history. They combine with the evidence of palæontology to convince us that this earth of ours is still young, active, and full of life, and that any process of ' running down ' is constantly being held by self-acting checks which are putting forward to vastly distant ages ' all prospect of an end.'

Biological Sciences.—While astronomy has given us the conception of illimitable space, it has done much to destroy what has been called the anthropomorphic view of creation. Geology, on the other hand, has endowed us with an almost limitless conception of time, but has done something to rehabilitate the importance of man as the highest product yet reached in the long history of the earth.

This it has done, in the main, through the intense reality that it has given to the conception of evolution. Although several authors, and two in particular, have pointed out that such a conception could not have been formed without the postulates of time and continuity of existence contributed by geology, it is hardly realised how much geological labour on the life of the earth, and on life on the earth, as summed up by Lyell and grouped and presented by him in his great work on ' The Principles of Geology,' was necessary to give to evolution a concrete and cogent application. The function of this labour could hardly be better indicated than by the position of geology as displayed in Lyell's earlier editions. The modern reader of them is continually haunted by the feeling that the author was struggling for a single missing generalisation which he failed to find ; and although, in almost every branch of the subject treated, Lyell leads up again and again to the missing conception, and though the facts and inferences which he marshalled can now be seen to be marching on this great idea, he never quite succeeded in attaining it for himself. It was left for Darwin, than whom no one was more conscious of what he owed to Lyell, to see that the facts must rest on some great single fundamental principle, to realise that this principle was evolution, and to apply it to his own branch, the development of life.

Lyell had proved that the long history of the earth as recorded in the rocks revealed the operation of causes, small in relation to the earth as a whole, but persistent, the majority of them still in action. It was a further debt to Lyell that Darwin should bring in the continuous operation of small causes as the machinery operating and guiding the evolution of life.

But though the work of geologists, as summed up in Lyell, provided the starting-point for the conception of organic evolution, it did not stop here. The idea of Uniformitarianism in which that work culminated was meant as a reaction against the fantastic operations postulated by the Catastrophists, and was never intended to imply that these causes in the past

were always balanced or distributed as they now are. There was in Lyell's statements nothing to indicate that denudation or earth-movement might not have been more active at periods of the past, that organic change might not accelerate or slow down, that there might not be variations in the trends of continental or oceanic development resulting in climatal and other changes, or that the very sources and intensities of energy from outside or inside the earth might not seriously vary. Only, warrant must be found for all such suppositions with regard to the earth of the past from fuller study of the earth of the present. And if we recognise the inner spirit which inspired the eloquent words of Lyell, when he had grasped that Darwin had supplied the one missing idea, we cannot fail to see that his Uniformitarianism included evolution as one of the 'existing causes' to be taken into consideration.

The physiology of the earth, however, is that of a very complex organism, and we are sure that we do not yet know all the forces internal and external acting upon it, still less their relative value and intensity, their distribution and variation in the past, or the precise records which each is capable of imprinting on the rocks of the earth-crust. But it is becoming clearer that there has been a periodicity in the stages of development of the earth-crust, and that on these great pulses of earth life there have been imposed innumerable waves of smaller cycles; and that, on account of their interference with, or reinforcement of, one another, the simpler type of cyclic repetition which might have been looked for in the history is masked and broken and diversified by actual happenings of an infinite variety. Van Hise more than once complained of the tendency of geologists to adhere to single explanations of events, and advocated the necessity of considering the co-operation of many causes; and it may well be that in many outstanding problems, such as past glacial or tropical periods, coral reefs, stages of earth movement, progression and regression of the oceans, we may find the ultimate explanation in the interaction of a number of 'true causes.'

Evolution.

During the long period of time comprised in the history from the Cambrian Period onwards, the slow and persistent evolution of plant and animal life went forward and left ample record in the rocks. To warrant a belief in organic evolution, we are no longer solely dependent on reasoning founded on existing organisms or on the facts of their ontogeny and distribution. As M. Marcellin Boule says in his work on Fossil Man, '. . . . pour tout ce qui a trait à l'évolution des êtres organisés en général, le dernier mot doit rester à la Paléontologie quand cette science est en mesure de parler clairement. Les plus fins travaux anatomiques, les comparaisons les plus approfondies, les raisonnements les plus ingénieux sur la morphologie des êtres actuels ne sauraient avoir la valeur démonstrative des documents tirés de la roche où ils sont enfouis et disposés dans leur ordre chronologique même.' * Although we are only too painfully aware of the innumerable chances that conspire to prevent an animal or plant from securing immortality by preservation as a fossil, the finding of better-preserved material, the more skilful preparation of it for examination, and the application to it of refined biological methods, such as careful dissection and the serial sections of Professor Sollas, are giving

* Marcellin Boule, *Les Hommes Fossiles*, 1923, p. 453.

us more complete and accurate knowledge than ever before. It may now be confidently stated that many of the most crucial links in the chain of evolving life are in our hands, that they actually lived in the past, and that their fossil forms show their relationship to their predecessors and successors. The time has come when Darwin's famous chapter on the 'Imperfection of the Geological Record,' an apology written with the most balanced criticism and unbiassed judgment, should be rewritten and revised.

It is true that we seem as far as ever from unveiling the points of divergence of the great phyla, and we can but feel that the time from the beginning of the Cambrian Period onward is but a small part of the whole history of life on the earth. As with antiquarian research, each new discovery in geology, whether on the physical or the biological side, only brings these distant ages more fully into view and emphasises their modernity and their likeness to our own time. Hutton's famous dictum that he saw 'no vestige of a beginning, no prospect of an end,' is to-day more true than ever, when we regard the evidence of stratified rocks. But we know enough to convince us that within post-Cambrian time evolution has steadily proceeded from general to special, from simple to complex, from lower to higher efficiency.

In almost every subdivision of the animal kingdom, and in not a few branches of the vegetable kingdom, lines of descent and directions of specialisation have been made out, sometimes visibly operating throughout whole Systems, but more usually through smaller divisions of the record; and this in the former kingdom not only among vertebrates but among the invertebrates and even their lower sub-kingdoms. It may even be stated that in methods of defence, in food-procuring in the attainment of favourable positions and attitudes, something very closely imitating what would be expected on the doctrine of the origin of species by 'survival of the fittest' has again and again occurred.

The essence of evolution is unbroken sequence, and when we consider the extraordinary delicacy of the adjustment of life to its physical and organic environment, the mutual interdependence of life forms, and the necessity to them of such factors as favourable range of temperature, food, climatic conditions, soil, and the continuity of the 'element' in or on which they live, it is most wonderful that in the vast lapse of post-Archæan time it has been possible for life to exist continuously, and continually to evolve, throughout those long ages. And this in spite of the fact that, although the main chain has been unbroken, conditions have, in many cases, been so unfavourable that whole groups have flourished and died out, while others have become so attenuated that only a few survivors have been left, highly restricted in distribution, to burgeon out again when the unfavourable conditions were removed, or in other places where conditions have again become more favourable to them.

That life has survived continuously in spite of the vicissitudes through which it has been compelled to pass, and the frequent convergence upon it of unfavourable conditions, may well be taken to heart by those who fear that civilisation will be brought to an end by the misuse of the powers that itself has evolved. They may surely take courage and trust that the remedy for these evils will come, as it has in innumerable other cases, not from conventions and understandings that, as all history shows, will

be mere scraps of paper, but from the intensive application to them of the very science which has evolved them.

Although the geological record is and possibly will always remain incomplete, it has yet proved remarkably representative, and certain outstanding facts have been made out which are sufficient to show that the lines of organic evolution as recorded in geology are in accordance with what is theoretically probable, and with those taken by the evolution of domesticated organisms and by human arts and inventions.

1. There can be no doubt that the stages of organic evolution are correlated with and were actuated by the stages in the inorganic evolution of the earth itself. That climatic change was effective in inducing migration, and thus in sharpening the struggle for existence against both enemy organisms and changed physical environment; that extension and restriction of land and water areas in some cases brought about keener and more varied competition, change of habit or food, and in others the destruction of potential enemies and the securing of the advantages of a fair field for the survivors; and that activity of the earth-crust in such things as deposition and mountain-building provided conditions for the existence of an increased range of varieties and the consequent struggle between them. If we are not allowed to say that this brought about the survival of the fit, it at least caused the destruction of the unfit.

2. It may be stated as a biological law that every locality becomes 'full' of life, forms arriving or evolving to take advantage of the special facilities offered. In consequence, resistance to the incursion of new forms, even if they are exceptionally equipped, is very great, and it is only occasionally that such new forms can make good their immigration. There are, of course, marked exceptions, but these generally occur when degeneration or overgrowth in size accompanied by neglect of means of defence have occurred, or when an area has been for so long sheltered from the wider and more general course of evolution that it has fallen seriously behindhand in the race.

The geological record gives indirect evidence of the same 'filling' of areas in the past in the extraordinary slowness with which advanced types, that have eventually made great headway, established themselves after their introduction; the earliest fishes, reptiles, and mammals are cases in point. Imperfect as the first members of these groups undoubtedly were, they must, even shortly after their introduction, have possessed considerable advantages over the older and established forms with which they found themselves in competition. In size and strength they were doubtless inferior, and probably they must have taken long periods to make good their advantage. But in all such cases the new forms went for a long period into 'retreat,' and, in face of the apparent slowness of their evolution and the bitter competition to which they were subjected, it is remarkable that they overpassed the troubles of racial youth, and eventually took the place to which they were entitled in the scheme of life. It seems justifiable to believe that there must have been at least some well-equipped types which did not survive competition in these early stages, but went under with all their promise of future success. We can easily imagine that the survival of such, had it occurred, may have altered the whole course of evolution and produced a life story very different from that we know to-day, and of which we ourselves form no small part.

3. Not less remarkable than the period of 'retreat' is that of booming development which at last came to each successful modification. In this connexion we can instance the '*pleine évolution*' of the graptolites, the euechinoids, ammonoids, and belemnoids, the fishes, reptiles, birds, and mammals, each in its own time. Each slowly but surely built up its supremacy, and then wantoned through long ages as the lord of creation in its own element and in its own day. Both the period of sanctuary and the subsequent boom can be closely paralleled by the case of many human inventions and in the occupations and history of mankind.

4. But while there are outstanding cases in which a line of advance is taken that is capable of successive improvements and leads on to continuous success, there are many other instances in which the line of advance, though temporarily advantageous, has only been carried through a limited number of stages, and eventually failed either by its inherent inadequacy or by imposing so heavy a burden on the economy of the organism that it was unable to bear the cost.

The only instance I need quote, though there are many others, is the use of defensive armour, spines, plates, hooks, horns, &c. These provide an obvious method of resistance to attack, and this defensive attitude has been practised by one group of organisms after another, but always with the same disastrous result, the imposition of a fatal strain on the organism to meet renewed, perfected, and more vigorous attack. The spinose graptolites and trilobites, the armoured fishes and reptiles, are cases in point, and in the last of these instances, at least, victory rested with the acquirement of swiftness in movement, accompanied by increasing power of attack such as is given by the development of teeth or claws or both. Again and again in the Tertiary Era one group of mammals after another, before, or more usually after, the attainment of great size, has taken to some means of sedentary defence, and in every case the cost of upkeep has been too great and the group has gone under. Every time the race has been to the swift, active, and strong, and those that trusted in 'passive resistance,' in 'defence and not defiance,' have gone under in competition with those that have been prepared to face the risks involved in attack. The fact that turtles and armadilloes have survived to the present endorses rather than vitiates the principle.

Other cases of rapid decline or sudden disappearance are more difficult to account for. The waning of the brachiopods but not yet their disappearance, the disappearance of the pteridosperms, the rugose corals, the belemnoids and ammonoids synchronising with the vanishing of many orders of reptiles, will long furnish subjects for research by biologists and geologists. And it may well be that the explanation will often lie along biological rather than physical lines, such as those suggested for the graptolites; Lapworth pointed out that their disappearance—in spite of a brave effort of passive resistance—synchronised with the great development of fishes, and the assumption by them of many of the functions previously discharged by the trilobites. In other cases the explanation may be more in the direction of that given for the reptiles to be referred to later.

The rarity in the geological record of some of the stages in evolution, and the absence of others which must surely have existed, may receive some explanation from what has frequently occurred in the history of human invention. If variants arise and are subjected to intense

competition, they have no chance in the struggle for existence unless they show rapid improvement and development of the favourable variations within a few generations. Hence the numbers exhibiting each of the early stages of change will always be few and the chances of their preservation slight. Those who have tried to work out the stages in the history of an invention, for instance, will appreciate the rarity of 'missing links' and the difficulty of filling in every step towards the later perfection. These are looked upon as 'freaks' and, unless they present real and marked improvement, are never manufactured on a large scale. Their numbers consequently are few, and many of them are the victims of experiment and often do not survive the experience.

5. Perhaps the most wonderful result disclosed by a study of the later part of the geological record is the steady and unbroken evolution of brain from the earliest vertebrate animals to the present. The exceeding slowness of the process in its early stages is not less wonderful than its acceleration during the latest stages of geological history. The disappearance of so many orders of reptiles at the end of the Mesozoic Period, at the close of a long and most promising chain of evolution, indicates that there was some inherent weakness underlying the line of evolution entered upon by them, which proceeded so far and favourably that it was impossible to retrace the path. This may well have been connected with the substance or construction of brain and nerve. If so, this side of evolution has to be seriously reckoned with, and it may be that the fundamental weakness of physical as opposed to intellectual evolution brought this flourishing and well-developed group to its end.

It has, of course, been suggested by Searles V. Wood, jun. (*Phil. Mag.* xxiii, 1862), and others, that the destruction of Mesozoic life types was brought about by physical changes; but, apart from the fact that the particular changes supposed by the former did not as a matter of fact occur, the entire explanation provides a cause utterly insufficient in comparison with the potency of organic struggle against creatures better endowed with warm blood, adequate brain substance, and the activity and enterprise springing therefrom.

In spite of the evidence of acceleration as the higher ranks of animals are reached, and in spite of the extraordinary efficiency of the human brain and all the benefits to the organism it brings about, we may well be appalled by the æons which have been used up and the millions of varieties which have passed away in the production of this, the most efficient scientific apparatus yet invented or evolved.

6. But if it has taken long ages to evolve an animal capable of a broader geographical distribution than any other, with a constitution capable of withstanding the widest ranges of heat and cold and of peopling the world from its tropical deserts to its polar wastes; and to endow him with a brain by virtue of which he has made himself master of the earth and all its living inhabitants; it has taken no less time for the evolution of the many factors without which his present success would have been impossible. To pick out a single instance, probably few things in the whole story of life have been more fruitful in effect than the appearance of the grasses in Late Eocene times, followed by their rapid evolution and spread in the Oligocene and under the direction of the critical events of the Miocene Period. Starkie Gardner in an admirable paper first drew attention to

the vital importance to the animal evolution of the world in general, and to the welfare of man in particular, of this step forward. It was followed by great changes in the insect world, by the rapid production of herbivorous mammals endowed with speed, great migratory powers, special dental and other anatomical adjustment to the new foods, and the institution in their herds of a discipline, subordination, and leadership which are almost tribal. These last qualities were rendered doubly necessary by the consequent rapid development of carnivora, and the need for scrapping passive and even active means of defence in order to secure the power, speed, and reserve necessary to follow their food harvests over great stretches of country. At the same time the habits and instincts thus brought about were those which man, by domestication, has been able to turn to his own ends. Thus at a blow, as the outcome of this stage of Tertiary evolution, there became available for mankind not only his chief plant food and drink, his luxuries as well as his necessaries, but his chief animal foods, together with his aid from the speed, strength, service, and endurance of the animals which he domesticated and to which he assumed the position of leader of the herd.

But while with the aid just described it was possible for mankind to progress far on the road of civilisation, progress would have been stopped, and as a matter of fact was seriously retarded, until the discovery and utilisation of the solar energy stored up in the earth's crust during the Carboniferous and subsequent Periods in the form of coal and other fossil fuels. The very exceptional conditions, climatal, geographical and botanical, requisite for coal formation, occurred all too seldom in geological history; but it has so happened that few areas of the earth are devoid of coal belonging to one Period or another; and the shaping of kingdoms and dominions has been such as to include supplies of fuel in most of them. Whatever may be the main sources of energy in the future, radiant, intratelluric, hydraulic, tidal, atomic, we have been largely dependent in the past, and probably shall continue to depend for many years to come, on that portion of the solar energy stored up by vegetation, and especially on that preserved in the earth-crust in the form of coal.

But again civilisation must have been greatly hampered or driven into a different course but for the agencies which have sorted out from the medley of materials of which the earth is composed, simple compounds or aggregates of compounds, or in rarer cases simple elements, in such a form that they are available for human use without the expenditure on them of excessive quantities of energy. The concentration of metalliferous ores, salines, and the host of other mineral resources has made perhaps the most important contribution of all to the latest stage—in good and evil—attained by civilisation.

Finally, doubt may be expressed whether man could have attained his present position if he had not made his appearance comparatively soon after a period of intense earth activity, when broad areas of newly raised sediment were available for occupation, when the agents of denudation and renewal were in active operation, and when a wave of rapid organic evolution was active. And a conjecture may be permitted that human evolution itself was probably hastened by the latest climatal severity through which the earth passed, the effects of which are only slowly passing away.

Much of what has just been said may revive recollection of an old Swiss guide-book which praised the beneficence of Providence in directing the dreaded avalanches 'into the desolate and uninhabited valley of the Trumleten Thal and in sheltering from them the beautiful, fertile, and inhabited valley of Lauterbrunnen.' However, it is far from my intention to imply that 'everything is for the best in this best of all possible worlds,' but only to point out, in reviewing the long chain of events of which we see the present end-product in civilised man, that within the ken of the geologist there have been many critical stages in the earth's history when any marked change in the conditions which then prevailed must inevitably have reacted profoundly upon the development of the human race when at long last it stepped out from the lower ranks to take the earth as its rightful possession.

Conclusion.

A review of the history and present position of geology shows that its better-known services to mankind have been in relation to the foundations on which industrial development and modern civilisation have been built—the mineral resources of the earth. These are many and various, all of them explored by geological methods. In every application of them we are again brought back to the primal essentials—water, iron, and fuel—and it is in the discovery and exploitation of these that the services of geology have been of especial value.

But in the course of the development of both the economic and the scientific sides of geology the principles discovered and elaborated have fertilised and enriched human thought as expressed not only in other sciences but also in the sphere of literature. As it has become more precise and is able to give a more accurate and detailed picture of the stages through which the earth passed during the long story unfolded by the study of the stratified rocks, it has shown that the earth, though only a minute fraction of the visible universe, has had a wonderful and individual history of its own. The keynote of this history is evolution, the dream of philosophers from the earliest times, now passed from the realm of hypothesis into that of established theory.

We are able to watch the evolution of the oceans and continents, of the distribution of landscape and climates, and of the long succession of living beings on the earth, throughout many millions of years. During these ages we see the action of the same chemical and physical laws as are now in operation, modified perhaps in scale or scope, producing geographical and biological results comparable with those of to-day. Hutton and Lyell discovered for us in the present a key to unlock the secrets of the past; the history thus revealed illuminates and explains many of the phenomena of the present.

And the outcome of it all is to endow man with a simple and worthy conception of the story of creation, and to fill him with reverence for the wondrous scheme which, unrolling through the ages, without haste, without rest, has prepared the world for man's dominion and made him fit and able to occupy it.

I desire to express my thanks to Mr. G. W. Lamplugh, Professor E. W. MacBride, Professor W. G. Fearnsides, and Mr. G. S. Sweeting for kind assistance in the preparation of this address.

SECTION D.—ZOOLOGY.

CONSTRUCTION AND CONTROL IN ANIMAL LIFE.

ADDRESS BY

PROFESSOR F. W. GAMBLE, D.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

'"*But what was the creature like?*" *I asked.* "*What like was it? Gude forbid that we suld ken what like it was! It had a kind of a heid upon it—man could say nae mair.*"'

R. L. S.—*The Merry Men.*

If I were asked to point out the main change in zoological thought since the last meeting of this Association in Canada, I should venture to say that zoological problems have become problems of control, and that control, from implying mere restraint, has come to mean 'quickening.' The being, well-being, and becoming of the animal in its world are no longer problems of statics, but of dynamics. The fabric of the animal body characterised by those traits and that orderliness that are revealed by genetic analysis is no longer regarded only as a link in the chain of organic affiliation, nor as a fact simply, but as the balanced result of controlled becoming or development. The factorial hypothesis and its corollaries convey this impression strongly. The results of ecological analysis, meagre as they are as yet, point to the same conclusion. Experimental morphology may be summed up in the word 'regulation.' Animal physiology shows the same dominant tendency. The results of tissue-culture show the existence of a process which enriches the body by enforcing it. The infinitely varied animal fabric appears to be the exquisitely balanced individual expression of processes that quicken and restrain.

This change from the older thought of the animal, as a mellowed, balanced product of changes under stress, has come from the renewed hope of understanding the natural problem in the new light of experimental analysis. If to succeed is to come up from below, the actual animal life that succeeds must be but a fraction of the submerged recessive life that experiment reveals. These recessives when artificially bred are no mere cripples, nor disconnected with the evolution of normals. They show us something of the depths of animal nature, and help us to realise that but for the grace of organic regulation we should be even as they. But the study of such analysis as a branch of zoology leads to an even more striking result. Not only does it reveal the existence of these sub-normals, but also it accounts for the defection of certain expected offspring. There are non-viable combinations of living substances. These entering the egg that should by expectation produce a male, render the egg incapable of

development. That family will be one of daughters only. The existence and the control of lethal factors is one of the most significant discoveries of the underworld.

It is with the results of one branch of this experimental study that I wish to deal. For several years experimental morphology has been actively pursued by zoologists in Europe and America. For the most part the egg has been selected as the natural point of departure, and the construction of the embryo or the development of the egg and of its parts has yielded results of great interest, though the search for a principle of organisation has not yet suceeded. To the developing organism it would seem to be all one whether it builds with one egg, with two eggs, or with a piece of an egg. (1) If there be any preformed or self-determined 'organisation,' it may be shattered to bits without prejudicing the appearance of a normal embryo. The nuclei of the segmented egg may be shaken about as a bag of marbles, yet there will still remain the capacity for normal differentiation. It is therefore not surprising that there is as yet no unanimity of interpretation. Some investigators seek the explanation of development in an innate 'organisation,' thereby postponing by a process of infinite regress the attack on the problem. Others assume by an unconscious *petitio principii* the very problem they set out to solve. Others take refuge in a metaphysical solution, and lately the problem of 'organisation' has been regarded as an ultimate category that stands beside those of matter and energy. (1)

Experimental zoology is a young science, and it is unlikely that we have reached Ultima Thule. Rather than regarding our position as one with our backs to the wall, I would ask leave to consider the report of the advance under the leadership of Professor Child of Chicago that has entered new territory. Instead of attacking the problem of the development of the organism from the egg, Child has long been working at the 'regulation' of regeneration and organic development. From his analytical studies (2) and (3) he has arrived at certain conclusions that have far-reaching consequences. Though based on the behaviour of the lower Invertebrates and Vertebrates, these conclusions have already proved of wide application. I believe I am right in stating that no more fertilising biological idea has been disseminated in the last ten years than Child's hypothesis of metabolic gradients. It has captured the imagination of the younger generation of zoologists and is exercising an increasing influence upon them.

The Individual considered as a Reaction System.

It is no easy task to express the principles of Child's theory of the organic individual without reference to fundamental questions on which differences of opinion prevail, and about which our knowledge is incomplete. Perhaps the best way is to give a concrete instance taken from the fresh-water Planarians, those highly organised 'animated pellicles' that divide by spontaneous fission. This process is initiated externally by a transverse constriction far down the parent body, but without any morphological distinction at this region. The tail-end after separation develops a new head, brain, eyes, and other organs. The head-end develops a new tail, and the process is eventually repeated. On turning up a stone in a stream running through limestone country one can find certain species of Planaria actively engaged in multiplication by this method.

Child's work consisted in applying methods of physiological analysis to this well-known process. He found that before any external sign of constriction had appeared, the intact and apparently single individual showed a hump in the curve exhibiting the rate of chemical change in its tissues, when tested from head to tail. The maximum rate of change occurred in the head region, and then fell off gradually to rise again to a lower peak before the caudal fall. The site of the second, smaller peak was the site of the future constriction, and of the future head of the coming daughter.

From this, and a large number of other experiments, Child concluded that the head of the parent exercised a variable degree of dominance over the subordinate individual that is represented by its own posterior end. External features were no longer the criterion of individuality, but merely the final expression of the physiological relation of dominance and subordination. The nervous system was but one expression of the embodiment of the dominant region (the brain) and of the track (nerve-cords) along which this region exercised its sway. This sway diminished in intensity with the length of the cords or distance from the dominant region, and it was this gradation of the influence of the 'head' on the 'body' according to distance that Child expressed as the 'metabolic gradient.' When the intensity reaches a certain minimum, those portions of the basal region whose potential is rising may assert their own hitherto suppressed individuality. They become almost physiologically isolated from the dominant region. The further conclusion therefore arose, that what we are accustomed to think of as an individual multicellular being becomes, when interpreted in the dynamic way, a composite being. The intact Planarian is only prevented from displaying its constituencies by the dominance of the head, but a number of circumstances may interfere with the dominance. As the head by growth of the body becomes removed from the tail region, the intensity of its influence wanes. If the conductivity of the channel of influence falls, the same result ensues. Again, should the tail become the seat of growth, or assert its independence by increase of size or in other ways, then the influence of the head is negatived. In all cases the head action is positive and not merely inhibitory. In all cases the basal action on the head is not positive, but indirect or inhibitory.

There are two special assumptions deliberately made by the author of this conception of organic individuality that require emphasis. The first concerns the independent nature of the apical region, the second the use of the term 'metabolic gradient.' The assumption with regard to the first is that the head or apex expresses the most intense and most intimate relation between the organism and its environment localised at one pole. Here the two are really one, and the head is the expression of this fact as a physiological, morphological and historic process. The other assumption is based on the physical basis of life as the seat of chemical changes and chemical correlation in which it is impossible to distinguish qualitative from quantitative effects, and asserts that controlled alteration in the rate of change (for example, of oxygen consumption) along definite gradients is the main 'cause' of that structural and chemical correlation that we call the base. The head or apical region is thus, in a derivative sense, self-determined. It is the animal at its highest; and as these largely

self-determined changes appear always to lead in animals to the formation of a central nervous system if they go far enough, the conclusion is reached that the nervous system is the final expression, both in arrangement and in mode of action, of the system of metabolic gradients.

A corollary of great importance can be deduced from the case of the Planarian. The degree of individuality of the daughter is a measure of the loss of control of the head-end, a not unfamiliar phenomenon. As this occurs, the daughter becomes more and more physiologically isolated and her metabolic processes proceed at a faster rate. Hence physiological isolation is a fundamental factor in asexual reproduction.

The Development of the Frog Egg as a System of Gradients.

In the light of this conception of the individual being as a reaction-system, we may now take the unfertilised ovarian egg, say of the frog, as a primary individual. It possesses an axial gradient. One pole is the region of highest metabolic rate determined by the relations of the egg to the maternal tissues and the other external agencies. There is evidence that, from this apical pole, chemical change proceeds in waves of decreasing order of intensity through the protoplasm towards the opposite or basal pole. Though there may as yet be no visible structural change in the colloidal medium, yet the factors that produce the first visible change are there. Differentiation on this view is the expression of chemical change along the gradient. The cell or ovum is in fact a creature 'with a kind of a heid upon it—man could say nae mair.'

The changes that ensue during the maturation of this egg or primary individual are too involved, and too familiar, to zoologists for me to enumerate. The little sphere, still without visible differentiation, becomes a stratified power-station. The apical pole remains chemically active, the basal pole accumulates stores of potential food and energy. The whole globular microcosm becomes enclosed in a non-permeable membrane, and is shut off as a closed system from the outer world. If only one of its extruded polar bodies returned; if only something could break this too, too solid envelope; if only some messenger from the outer world, some Orpheus could visit the cold Eurydice, then development might begin. And it so happens. In the natural sequence, Orpheus—the spermatozoon—is the winged key that unlocks the imprisoned one. He casts a shadow—the grey crescent—that heralds the advent of the new gradient, the one that takes sides, and that prophetically unseams the germ from the nave to the chaps, that separates the right side from the left. As if to justify the use of emotional language, the germ at that moment of release takes an explosive breath as though the crisis were over. It will never take a deeper one. The process of development is begun.

The first trace of the embryo is the apical region or brain, formed as part of that region of greatest metabolic activity known as the dorsal lip of the blastopore, or the 'differentiator.' (4) This region provides the three co-ordinate lines or 'metabolic gradients' along which the main features of structure are elaborated—the primary gradient along which the central nervous system forms; the secondary gradient for the axial organs; and the transverse gradient along which the lateral organs are developed.

The fate of the cellular material with which the differentiator deals depends not on their pre-determined nature but on the changes they undergo in passing to their final place in the organism, and to the company they keep when they get there. So far as their fate is concerned they may say with Hamlet 'the readiness is all.' In the hands of the three co-ordinate gradients that radiate from the 'differentiator,' it matters nothing whether the cells they hand on to build the back or the side are those naturally presumed to fit the part. Cells that would under normal circumstances form skin cells on the outer surface, and that lie outside the reach of the differentiator, will if grafted into it become kidney-tissue, muscle-tissue, or gut-tissue. And the converse is true. Tissue of the differentiator itself, presumably destined to become kidney or muscle, may be grafted into the wound left in the skin by the previous excision, and there it will become skin. So the surface tissue that would become brain if left alone will, if grafted into the differentiator, become intricately involved, and after travelling inwards and forwards find itself transformed into the likeness of those with which it is now a companion in function. With increasing zest we may repeat Huxley's great metaphor concerning the cells of the early embryo: 'They are no more the producers of the vital phenomena than the shells scattered along the sea-beach are the instruments by which the gravitative force of the moon acts upon the ocean. Like these, the cells mark only where the vital tides have been and how they have acted.'

The events that I have briefly described constitute the prelude to two other phases through which the life of a multicellular animal passes. We may call them collectively the indeterminate, the determinate, and the integrated phases. During the first, the three waves of chemical activation assort the cellular material along the axis of the body and next determine irrevocably its fate as organs of the individual. This period begins in the frog with the closing of the blastopore and of the neural groove. From now onwards the evolution of the organs proceeds from determined beginnings impressed upon the constituent cells by their relation to each other and to the gradients. Remove the rudimentary organ from its normal position—the heart, the kidney, and the brain—and it will complete or at least continue its evolution even in the solitude of a moist chamber. But under normal circumstances this phase of organic determination leads insensibly to that condition of full and inter-related activity that we may call integration. The muscles may be able to develop apart from the nervous system, but without organic contact with that controlling system they cannot function. The kidney may exhibit characteristic complexities of origin and evolution without the aid of humoral or hormonic influence, but it cannot function apart from these. The primary factors of life—the metabolic gradients—are supplemented by new structural factors and new chemical factors, and together constitute personality.

Meanwhile, the inevitable price, senescence, is paid for advance. The stream of animal life, unlike its prototype, sedimenting most elaborately where it runs most strongly, is running down. Stability of construction brings the penalty of diminished dynamic activity, and the advent of puberty marks for many animals the shadow of the fell sergeant. But life has still its reserves, or at least one means of continuing the life-cycle in its descendant, if not in its undivided personality. In those lower

animals of ponds and streams, the Planarians, the act of procreation can be both naturally and artificially checked, and a return to a less highly organised state can be induced. In a similar way the act of sterilization induces fresh vigour in some of the higher animals. Finally, in many animals the body undergoes periodic retrograde evolution, renews its youth, returning to an undifferentiated state in which it passes the winter with heightened powers of resistance, and on the advent of spring redevelops its organisation.

Evidence for the Hypothesis of Metabolic Gradients.

(*A*) *Axial susceptibility.*

The evidence for these far-reaching conclusions as to the nature of the living organism is partly direct and experimental, and partly indirect and observational. The direct evidence has been drawn from experiments by Professor Child and his school on Protozoa, Coelenterata, Planarians, Liver-flukes, Annelids, Echinoderms, Fishes and Amphibia extending over about fifteen years. Recently Dr. Shearer (5) has repeated these experiments on the chick and on earthworms, with results entirely confirming the conclusions of Child and his pupils. A critical review of the evidence has recently been published by Child and Bellamy (5*a*).

The first class of evidence relates to axial susceptibility to the action of toxic or narcotic substances. When immersed in, for example, a weak solution (0.001 mol) of potassium cyanide in well-water, the 'head-end' of the whole animal or the apical pole of the egg is the first portion of the body to undergo disintegration, and this is followed by a succession of stages during which the process slowly spreads downwards. In general, the susceptibility-curve plotted on the basis of time-ordinates against these stages as abscissae, shows a much sharper fall for young than for older animals of the same species if the solutions are above a certain degree of concentration. If very dilute solutions are used, the opposite result is obtained. Immunity is gained more rapidly by the young than by the old. These results may be explained as due to the action of the cyanide on the oxidation-process and possibly also on the physical character of the colloidal protoplasm. The important point is the definite relation of disintegration to the animal's axis. The 'head-region' or the apex of the egg disintegrates first and the basal region last. The evidence therefore tends to show that the susceptibility gradient is evidence of the existence of a metabolic gradient.

Estimations of this kind have been made by the use of a large number of narcotics and poisons and the results have been confirmatory. More recently, other methods of testing the presence, course, and strength of these gradients have been devised. Dr. Tashiro (6), for example, has applied to the nerves of the body an exceedingly delicate test (the Tashiro biometer) for the estimation of carbon dioxide in minimal quantities, and has shown that a gradient exists following the direction of the impulse along the nerve. Again, Child himself, and later Shearer, have demonstrated the presence of axial gradients in starfish and chick respectively, by the use of acetone and other substances, which are precipitated in the tissues of the living developing animal by oxidation, thus giving an ocular demonstration of the track of the primary gradient. Unquestionably

the development and application of biochemical methods will indefinitely increase the weight of this testimony, but the main thesis appears to be established, namely, that there is direct evidence of the presence of a primary metabolic gradient along the major axis of the body.

The indirect evidence is more easily appreciated by the general body of zoologists, and it is of the greatest interest. If the value of a hypothesis consists in the number of phenomena that are subsumed under it, then the gradient hypothesis on morphological evidence alone may take high rank. Old-established facts acquire new meaning.

The general succession of cellular events in animal development shows that the fertilised egg has a radial or bilateral symmetry before it exhibits cell division. Normal and experimental evidence point clearly to the conclusion that the first act of morphogenesis is the establishment in most animals of the head end, and in Coelenterates of an apical region. This is followed by the development of the dorsal surface in Vertebrates, and of the ventral surface in most Invertebrates, determining in each case the foundations of the nervous system. Simultaneously the lateral organs are laid down usually in the form of ' segments,' the outer part of which remains more embryonic and plastic, whilst the inner part, abutting on the axis of the embryo, undergoes more rapid and elaborate morphogenesis. The whole process of the gradual establishment of the primary rudiments of bodily structure in the embryo is not only consistent with the theory of gradients, but receives (perhaps for the first time) a rational ' explanation.'

(*B*) *Regeneration.*

Perhaps even more suggestive than the facts of individual development are the conclusions of experiment, both natural and artificial, upon the regeneration of animal organs and tissues. The main facts as to the extent and occurrence of the faculty for renewal of lost parts by animal tissues are well known, and need not be traversed here, but there are some special cases that are little known, and that form a test of the validity of the gradient hypothesis. Moreover, as this view grew out of the consideration of data given by the regeneration of animals, it is appropriate that this large body of analytical work should receive mention.

Child's work, and that of his pupils, has shown that in certain freshwater Planarians, only experimental difficulties set a limit to the minimal quantity of the body that will regenerate the whole. If and when these difficulties are overcome, it is probable that a single isolated cell of many of the lower animals may be induced to regenerate the whole, as is the case in many plants. We are only at the threshold of these inquiries, and the progress of tissue-culture, which is now being actively pursued, will undoubtedly open up new ranges of control over the technique of physiological isolation. It will be remembered that H. V. Wilson and J. S. Huxley (7) have shown that from the artificial fragmentation of a sponge or hydroid, new individuals arise. From a few of those fragments—sheddings composed of cell-groups, and even a few isolated cells placed in suitable conditions—there arises by cellular conjunction a small amorphous mass, which acquires polarity and differentiation, and forms a new sponge or hydroid, recalling the reconstitution of ' an exceeding great army ' in Ezekiel's vision of the valley of dry bones. We seem driven to the conclusion that every cell of these animals only develops a portion of its potentiality when actively

functioning as a part of the whole, and that each cell has in addition the opposite faculty of dedifferentiation—of becoming young and resistant at the same time. When this rejuvenated cell develops either singly or in company with other dedifferentiated cells, the resultant in either case exhibits a new metabolism and a new orientation, giving rise to an organism with typical arrangements of dominance and subservience of parts, such as characterise all normal animals.

The morphology of fixed colonial animals such as corals acquires fresh interest when considered in the light of this principle. Wood-Jones (8), as Child has pointed out, has found from a study of living Madrepora under natural conditions, that there is an apical radially symmetrical zooid at the top of the stem which give rise by budding to bilaterally symmetrical lateral zooids. These, however, do not bud off others so long as the apical zooid is present and active, until by growth of the whole 'shoot' they become separated by a certain distance from the dominant apex. When that occurs, one of them becomes transformed into a radial member, puts out lateral zooids and becomes a new apex. If the apical shoot and stem are removed, several branches may arise by transformation of bilateral into radial reproducing zooids. The whole process so strikingly recalls the fundamental relations of dominance and isolation leading to organic reproduction in animals and also in plants that Child does not doubt the general applicability of the principle to organisms in general.

(*C*) *Independence of the Apical Region.*

One of the most striking pieces of evidence on the subject of regeneration is the work of Ivanov on certain sea-worms, Spionids and Serpulids. Unfortunately, the greater part of the work (1912) is in an inaccessible Russian dissertation (9), but the first part of it appeared in 1908 as a continuation of his earlier researches on *Lumbriculus*, a fresh-water worm. In order to make the results clear, reference must be made to Ivanov's division of the Annelid body. By reason of certain peculiarities of the mesoderm of the anterior segments, he accounts as cephalic, or, as he later calls them, 'larval' segments, not only the prostomium and peristomium of zoological nomenclature (*i.e.* the apical and sub-apical segments), but those which follow, so long as they possess certain mesodermal characteristics. The rest of the body he calls 'post-larval.' This post-larval body is specialised in Serpulids into a thoracic and an abdominal portion. If now 'the head' or three larval segments of Spirographis be removed, the process of regeneration is no simple or direct operation, but resembles, to a remarkable degree, the embryonic development of these segments; whilst the regeneration of the body-segments proceeds in a different way, but also along the lines of the embryonic development of that region. What, however, chiefly concerns my argument is the establishment of a new head, not by morphollaxis (dedifferentiation followed by reconstruction on a new type), but by the appearance of an apical plate typical of the trochosphere stage, of pre-oral antennae (which have disappeared from the Serpulid trochosphere), and of the cerebral ganglia by thickenings that correspond to the ciliated pre-oral bands of the trochosphere. The interior of this dedifferentiated thoracic end of the decapitated body is now filled by immigration of ectoderm cells that assemble in three

groups or segments, one of which gives rise to the corona so typical of Serpulids. In the meanwhile, the posterior part of the body is reconstituted into thorax and abdomen.

It is most desirable that these results should be fully tested on fresh material, but taken in conjunction with the work of Allen on *Procerastea* (10) and of the many workers on *Lumbriculus*, they point to the special nature of the apical segments of the body. Allen has shown that each batch of four or five segments taken from different portions of this Polychaet reorganise the whole, in such a manner, that the initial segments occupy the same relative position in the regenerated worm that they did in the parent animal; and Ivanov has shown in *Lumbriculus*, that the histological development of the seven anterior 'head' segments follows a different course from that of the rest. Child has concluded from his studies on Planarians 'that the head which appears in the reconstitution of a piece is not physiologically part of the piece and is not formed by the piece, but develops, so to speak, in spite of it.' (2. p. 113.) This is a hard saying, but we may bear it, if the facts I have given as to the process of head-formation in Polychaets are borne in mind. They show that the metabolic and morphological changes evoked by section are not those characteristic of the neck region in which they arise. They pursue a course of their own analogous to that followed by the normal pre-oral or apical lobe, and produce a complex structure in which the brain appears as a new development; whilst further back the new differentiator leads to the independent new formation of the mesoderm of the thorax and abdomen. The whole process is strikingly reminiscent of the two similar lines of metabolic activity in the embryo of the worm or of the frog, and constitutes confirmatory evidence of the existence of a co-ordinated system of gradients.

A peculiar corollary arises out of a consideration of animals that may possibly present two apical regions at opposite ends of the major axis. I venture to suggest that Lamellibranchs might prove unusually interesting if examined from this point of view. It is also possible that Cestodes would give interesting results, especially in the case of those irregular growths known as *Sparganum*. One of the virtues of this hypothesis is that it makes old things new and suggests new problems for investigation. Above all, it has led to the power to predict and control the results of experiment on two groups of animals, the Oligochaetes and the Planarians.

Summing up the evidence adduced in support of the 'gradient hypothesis,' I am inclined to regard its value as indicative rather than demonstrative of that hypothesis, as its suggestiveness exceeds, in my opinion, its conclusiveness. Above all, this hypothesis suggests, and suggests perhaps for the first time, a method by which the problems of development can be linked up with those of genetics.

Periodicity as a Fundamental Mode of Action.

The animal according to this view is a system of periodic change. The system, as a whole, tends to slow down, but each part of it, each organ, works in shifts which permit every working group its period of rest. While resting, their capacity for output is increased, and on working again their rate of metabolism rises, falling again as the function progresses. Cycles of activity and morphological cycles are essentially age cycles. In the

higher animals, the organism as a whole becomes, under conditions of our present imperfect control, irrevocably older, and each cycle of rest brings with it less rise in metabolic rate. In the lower animals and in hibernating members of the higher forms, extensive rejuvenescence takes place. The senile effect is indefinitely postponed. Physiological isolation of a part occurs from various causes—increased growth and relatively decreased subordination to dominance, position off the line or beyond the main force of the gradient. Such isolated regions re-acquire the higher rate of metabolic change, and establish a new gradient system or a renewed system based in either case on local differences in rate of stimulus. Such physiologically isolated pieces we call germ-cells, buds or spores, but there appears to be complete gradation between the rhythm or cycle of rest and activity in the functional units of an organ, and the periodic ripening, discharge and activation of ova or the periodic production of medusae and of resting stages of Polyzoa or Sponges. To use Professor James Johnstone's phrase, the tendency of the universe to run down, or of entropy to increase, is opposed by phases in the cycles of life. The alternation of the physiologically younger state with the more highly differentiated older state is fundamental.

Periodicity in Organic Function.

Intimately connected with the idea of the organism as a synthesis of co-ordinated control is the principle of periodicity in the functioning of organs. This is a development of an old idea and is widely recognised by physiologists and pathologists. It may be expressed in the phrase that at any time the organism or any part of it, is a function of its own cyclical period, or, as I have just expressed it, an animal works its organs in shifts. What the shift-unit may be for each organ we do not know ; we do know that, for the higher animals, more tissue exists than is needed for well-being under average circumstances, and that when a time of special stress ensues the emergency is met, not so much by increasing the pressure on the working shift, as by calling up the reserves and throwing them into the general action.

The evidence for 'partial activity,' as the pathologists call this economic exercise of function, is partly direct, by tests indicative of activity or repose, and partly by the results of observation on the removal of organs or parts of organs. The glomeruli of the mammalian (rabbit) kidney have, by suitable means, been made to show their fields of activity at a given moment, and the result shows patches of active glomeruli alternating with inactive ones. Again, removal of a large portion of the liver is not necessarily fatal to man, nor is it essential that both kidneys should be present. Removal of one of the kidneys and a study of the after-effects confirms the conclusion that one kidney can do the work of both, and that a much smaller liver than is normally present can sustain the body in health. Similar conclusions apply to other tissues, and there is great need for the extension of research on these lines to the partial activity of animals.

Two considerations of great practical importance for our present study of control as a principle of organisation arise out of an analysis of this view of cyclical functioning of parts of an organ. The first is that the resting shift is receiving less blood and is more resistant to disease than when it is working. It is in a state of less active metabolism, and while recovering

from the effects of its spell of work has become temporarily physiologically younger. The second consideration is that the age of the animal counts as an important factor in the final result. The removal of one kidney from an adult throws the entire excretory function on to the other, and thereby increases general susceptibility to disease or breakdown where previously only local susceptibility occurred. But in the case of a child the result is quite different. In this case, the remaining kidney develops its reserves, forms additional tubules and glomeruli, and ultimately attains a volume equal to that of the two original organs. It is thereby enabled to continue its action on the lines of partial activity, and to afford each of its functional units their periodic phases of activity and repose. I trust that I may be pardoned for taking a leaf or two out of the book of pathology for the purpose of illustrating, not only the principle of control, but also the great benefits to biological sciences that will accrue by a fuller mutual recognition of the advances made by pathologists and zoologists.

Nervous Control.

Another outstanding example of the working of control in the organism is afforded by the progress of neurology, in which your own earlier nominated President and the President of Section I for this meeting have taken such a prominent part. The brain of man is now regarded as a hierarchy developed for control. The existence of its members, their activity and degree of suppression or of dominance and subordination, as well as their intricate relations to the body and its environment, are matters of interest to all of us, and their consideration may fitly introduce the larger aspects of control with which I shall presently deal. The brain is, in fact, the highest expression of the activity of that co-ordinated system of metabolic gradients which integrate the physical basis of life into individual being. If I may venture for a moment into these deep waters, it is rather to illustrate the existence of control than to expound that relation of the nerves to the gradient hypothesis upon which Professor Child has recently issued a special memoir (11).

The well-known experiments performed on the arm of Dr. Head, and since repeated by others, revealed more fully than before the normally suppressed nature of the thalamic complex. The acute but uncritical sensations that he experienced during the return of sensibility—the protopathic form of sensation—represent in all probability an early stage in the sensations of vertebrates, and one connected with the optic thalami as that primary group of centres in the stem to which all sensory impulses converge. The subsequent return of normal epicritic sensibility marked the relative suppression of the thalamus by the higher cortical centres in the neopallium. The experiment caused a release of suppressed function. The lower order of the hierarchy was, for a time, allowed to exercise something of that disorderly, acute, and uncritical sensibility which has been in part incorporated into, but largely suppressed by, the more critical and dominant centres of the cortex. In some such way, the control that civilisation exerts upon society is thrown off by its retrograde units who indulge in disorderly, acute, and uncritical actions until forcibly restrained from so doing by the higher powers.

In connection with the subject of nervous control and the development of social life, I should like to draw attention to the social insects whose

activities have lately been reviewed by one of the most scholarly entomologists of the day, Professor Wheeler. In his new book on the subject (12), Wheeler mentions, without, however, stressing the significance of the subject, that the advance from the solitary condition (that is, a pair of wasps, bees, or beetles making separate nests) to the social state is associated with two factors. First, the mother does not, as do the solitary forms, die after oviposition, but in virtue of special food she is able to survive the birth of her offspring; and secondly, and more significantly, she touches them and they touch her in the act of feeding. It is this touch of nature that seems to make real kinship between mother and offspring, and that provides the starting-point for the development of that highly specialised group of societies into which insects alone have the entrée. It would be of the greatest interest to make a comparative study of the nervous system (particularly of the brain) of those bees, wasps, and beetles that exhibit the first touch of social genius. In its more advanced forms, control exercises the most diverse influence upon the whole economy of the insect society that practises it, one of the most curious being the control of the digestion of a specialised article of diet (wood pulp) by the Flagellates that live symbiotically in Termites. Termites have apparently discovered and exploited the cytolytic ferment that these Flagellates exert, and by a process of rectal feeding of their own young they ensure that each larva is provided with the necessary digestive ferment.

The Control of Environment.

The organism, however, does not exist except as relatedness. We are too apt to abstract it as a concept from its inner environment and from its setting in the outer environment which are really part of its being. The acid test of this proposition is the mature but unfertilised egg. As I have pointed out, this microcosm is a system of readiness for complex and energetic development, but is without contact with the outer environment. It is a closed system. It is physically as well as physiologically alone in the world. It hovers between life and death. As a (physiologically) highly differentiated system, formed late in physiological history of the individual, it is what Child calls a senile cell. Tested by the susceptibility method, by respiratory exchange and by heat production, the mature egg of most animals is inactive, and, in contrast to the rate of change it will exhibit if fertilised, may be said to be inert. If now this closed static system is put in relation to the outer world, the response is immediate. Drastic changes convert the static into a highly dynamic system. A dynamic relation between the egg and its environment is then a necessary condition for the initiation of development, and the ' environment ' of later stages is but an elaboration of the ' relatedness ' opened up by fertilisation.

The internal or humoral environment, elaborated by the organism and controlled by its hormones, forms one of the ' normals ' of the higher animals. This chemical correlation is associated with the acquisition of external normals largely but less surely independent of changes in the outer world. The place in nature, the environment that has become, as it were, part of the organism—constancy of temperature, steadiness of balance in the face of altering conditions—is gained *pari passu* with the establishment of normals of internal environment. Regu-

lation of its place in nature, 'choice' of environment (including the presence of other organisms as well as the conditions of life in the restricted sense), adherence to a selected field of outer impulses, constitute an essential feature in that relatedness which constitutes individuality. 'I am part of all that I have met.'

A few illustrations taken from recent ecological work may not be unwelcome. Mr. Eliot Howard (13) has concluded that spring migrants to England each after their kind select and guard a territory on their arrival. The distinctive song of the cock announces this achievement to the later flight of silent passing hens, and mating is but a prelude to a continuous policing of the stretch of hedge, area of moor, or piece of covert whose boundaries, to us invisible, are clear to them. The intrusion of another cock of the same species is hotly resented, and fierce engagements, extended it may be, to the cocks and hens of other species, are continued, up to the boundary and then suddenly cease. The bird and its environment—the territory—have become one activity, and it is restless till it has established itself in its niche. Just so, to take a more familiar example, each member of a Council or Parliament at each sitting has to regain his orientation both to place and to person before he can be at rest and at his best. As J. S. Haldane has put the matter, 'regulation of the external environment is only the outward extension of regulation of the internal environment . . . An organism and its environment are one' (14, p. 99).

If we now apply the principle of physiological isolation to the organism as influenced by, and influencing, its external environment, many well-known facts of zoological distribution become intelligible. Isolation arises from many different causes—by isolation by growing size, by decrease in conductivity in the path of transmission from the dominant region, by decrease in dominance itself, or to a change in the conditions of life—and no general statement can be made that will cover all cases. Bearing in mind, however, that life under dominance tends to exhaustion, whereas isolation leads to the renewal of activity at a lower level of complexity, we should be prepared to find that organisms change their environment with change in their physiological conditions, and that historically there would be 'backwaters' of those stocks that represent ancient stages of more progressive races; and we should further expect that these 'islands' would possess a higher metabolic rate than the more differentiated and highly integrated races. To them rather than the dominant races we should expect the future to belong. From others, like them externally perhaps, we should expect neither progress nor repression, but a balance that, indefinitely perhaps, postpones the evil day.

These relations we do find. The indefinite persistence of Lingula and Nautilus on the mud flats and depths of the Fijis in the Far Eastern seas, of Pleurotomaria in the Far East and West, the general isolation of 'living fossils,' is on this view to be regarded as a balanced senescence. Even in the most progressive regions of the world there are islands or backwaters where such arrested balance maintains a precarious existence. Proteus and other primitive forms survive only in the Balkan peninsula. Primitive societies of mankind or primitive customs likewise survive in those isolated communities of a progressive race. Modern industrialism creates such islands where the raw material or the working conditions demand isolation

from the larger towns, and in this way acts favourably to the biological future of the island communities.

The question as to what determines or inhibits the 'progressive' development of an isolated animal or human group, provided as it is with an actual or potentially higher metabolic rate than that of its more dominated portion, is a question of the greatest interest. In so far as isolation leads to greater 'individuation,' we may look to the isolated as the source of fresh individuality and power to wield dominance, to be paid for in time, however, with the inevitable price of diminished progress. A careful survey of closely allied species in certain groups of animals (Fishes, Echinoderms) has shown that the nearest allies of a given species occupy widely separated areas. Thus, the common European Starfish has its nearest ally on the opposite coast of Canada and America, and the sea-urchin, *Echinus esculentus*, has its nearest ally in blood far removed in space. Canada and Scotland might serve as a typical example. Just as conditions of existence form one of the factors governing isolation, so the readiness to make a change of function in 'adaptation' to a consensus of favourable conditions may determine the advance. The heightened metabolic activity of the isolated ones may then profit by the new environment which they incorporate into their new individuality.

Professor Elliot Smith has emphasised this view of the origin of civilisation. If, as we all hoped, he had addressed you, I venture to think that in his mind, if not expressed in his words, would have been that thought 'the readiness is all.' Many tides in the affairs of men may have washed the islands of the strong isolated groups before their concurrent benefit was grasped and developed. Egypt and Western Asia was not the only area where the earth would have seen the birth of civilisation, but elsewhere, perhaps, the readiness was lacking even if the physiological impetus was stored in the biological history of the people. So it may have been with the history of animals and so it may be in the future. 'In the reproof of chance lies the true proof of men.' Yet chance has other gifts than harsh reproof.

Zoology as a Factor in Civilisation.

When we consider the principles of periodicity of regulation in form and function, and of that characterisation of successive generations which constitutes genetics, we cannot help concluding that, so far as they are fruitful in stimulating inquiry and true to the best of our limited critical knowledge, they should serve to a much larger extent than is now the case in human thought and endeavour. I am not now referring to such knowledge as having merely a pragmatic sanction. Usefulness is not the justification for the study of biology. Wisdom is justified of all her children. It is because we are the outcome of the biological process that a science of life will provide men with a truer understanding. Biology in the Greek sense will be founded on the biology of science.

Such recognition of its basal position has not yet been obtained by biology. The progress of industrialism, the application of physics and chemistry to national needs and national entertainment have won, for physical science, an appreciation and a belief which, even if unreasoned by the majority, has, I believe none the less, that sanction which gives weight

to convinced public opinion. Nor are there wanting those who look to the development of physical science, alone or in the main, as the lodestar of modern civilisation. They may point out that even in those industries, such as animal and plant husbandry, that are most biological in character, the subject-matter so far as it is biological is dealt with in an empirical way, untouched by modern biological principles. The selection of new varieties, and the whole process of animal breeding in the world of racing and agriculture, is a cult now as always entirely cut off by science, but possessing the vigour and initiative that physiological isolation confers. The real ecologists are those—the fishermen, hunters, trappers—whose wonderful empirical knowledge and nomenclature contains more than can be reduced to the dimensions of that bed of Procrustes, our formal science of animal life. The advocate of physical dominance might even go further, and suggest that just in as far as modern civilisation had spread, to that extent had biological interests receded; that the world of biological evolution, the natural faunas and floras of the unmastered spaces, were bound to succumb to the dominance of civilisation; and that unless the biologists take heed, their very material for study will be reduced from the irreplaceable and almost infinitely rich variety of the wild, to the monotony of the house fly and house sparrow, and biology will become a mere *ancilla* to medicine and gardening.

The *advocatus diaboli* has put forth his pleadings. How is the counsel for the defence to state his side? He can point to the need for taking the long view. He is convinced that man as man, and not as a temporary phase in an unstable scheme of things, is a biological creation; that as part of his invincible faith in evolution, the study of the products of evolution will throw light on man's body, mind, and destiny. But just as dominance and freedom from dominance are creative but correlative, so the over-mastery of a dominant scheme, the tyranny of organisation may lead, after a period of effective differentiation to a slowing down of the national spirit. The reaction, the return to individualism, the principle of isolation as I have called it, is the natural result. The problems of social philosophy, even the problems of government and civil life—biology in the Greek sense—are illuminated by the principles of zoology, and if the flame is at present flickering, weak, with little pressure behind it, there are those in this and other countries who have faith in its future brightness. This light shining strongly in the west, is a rising star. The astronomer will be satisfied to take his pleasure in its understanding, but it will also pilot the way for those who in many countries have long wanted a lamp to their feet and a light to their path.

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INTER-RACIAL PROBLEMS AND WHITE COLONIZATION IN THE TROPICS.

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I. The Modern Increase in Population.

The problem of the present century, according to many observers, is the problem of the colour line. We are warned from one side of the danger to civilization of the rising tide of colour; and from the other of the peril to humanity from the rising tide of colour prejudice. The difficulties of the racial problems have been intensified by the unprecedented increase in the world's population. According to the estimates in 1696 of Gregory King, a pioneer in political statistics, the utmost population which England could support would be 22 million and that number would not be reached

until the year 3500 or 3600—'in case the world should last so long.' In the year 1900, according to his expectations, the population would have amounted to only 7,350,000. These egregious miscalculations are a warning of the uncertainty of statistical forecasts as to population and an illustration of its surprisingly rapid increase in the modern world owing to the application of science to commerce, industry, and public health. This accelerated increase is mainly due to the European race, but it has been most rapid in Africa and Asia in consequence of the reduction by European administration of internal war, plague, pestilence, and famine. From 1906 to 1910, to quote the latter half of the last normal decade, the population of the world grew at the rate of doubling in sixty years. If this rate were to be maintained the 6,600 millions of people, which it has been calculated is the most that the world can feed, would be in existence in 120 years; and even if the food supply were indefinitely multiplied by the precipitation of the nitrogen of the atmosphere as a constant rain of manna, standing room on the earth, exclusive of the remoter Arctic and Antarctic lands, would be all filled when the population numbered 700 billion (*i.e.* million million) in the year 3000.

The rapid increase in the population of the world during the last half-century has had disturbing political influences. Thus many parts of India have apparently almost the maximum population possible under existing economic conditions, and the slow present increase is gained painfully to the accompaniment of irrepressible discontent. Countries which once had extensive empty lands have begun to close their ports to aliens, in obedience to the principle that each land must consume its own surplus population. The United States, the 'melting-pot' where the mixed races of the Old World were being fused into a new type, has adopted measures based on the growing belief, in the words of Lothrop Stoddard, that 'the book of race migrations must be closed for ever.' The halt at Ellis Island has already warned eastern and southern Europe that America is no longer an open asylum for refugees. The three great natural outlets from Asia have been closed by the prohibition of immigration thence into western America, by the 'White Australia' policy, and by the refusal of eastern and southern Africa to accept further Asiatic contributions to their needed enlarged supply of labour. The struggle for expansion, which was the ultimate motive of the World War of 1914-18, will inevitably be still more bitter and terrible if it become a struggle for existence between the White and Coloured races.

The effort to foresee the future progress of the world raises two contrasting visions. The increase in the wealth and prosperity of all the continents by the influence of the European race may be continued, either by colonization, as in America and Australia, or by administration, as in Asia and Africa. Asia, by improved industrial methods, and Africa, relieved from the slave trade, may continue to advance in co-operation with the European race instead of under its government; and European control may be voluntarily withdrawn as sympathetic alliance replaces the older systems of servitude. If those developments take place the twentieth century will be indeed a golden age.

The alternative picture is darker. Europe, during the past fifty years, like Portugal in the sixteenth century, may have taken on tasks beyond its power. The drain on the manhood of Portugal by its vast colonial

empire reduced the home population by half, the land went out of cultivation, the country was stricken by famine, and Negroes were introduced to till the derelict farms and then absorbed into the nation. The dilution of the Portuguese by Negro blood is often regarded as one of the main causes in the fall of Portugal from its former political, scientific and intellectual pre-eminence. Has Europe been led into the same enterprising but disastrous error? Has it undertaken the administration of larger areas than it has the *personnel* to maintain? Will, for example, the African troops in France have a similarly demoralizing effect as the Negroes in Portugal and the slaves carried into Italy during the decline of the Roman Empire?

II. The Races of Mankind.

Consideration of inter-racial problems requires a classification of the races of mankind. The most popular classification is that into four races based on colour—the white or European, the yellow or Mongolian, the brown or non-Mongolian Asiatic, and the 'black' or Negro. These colour names, however, are only valid if used in a conventional sense, which is often inaccurate.

The character of the hair forms a more reliable basis and it divides mankind into three primary races—the Caucasian, Mongolian, and Negro. The Caucasian has abundant wavy hair; the Mongolian long, lank black hair; and the Negro short woolly hair. This classification is only politically suitable if the Caucasians be subdivided into two sub-races, the fair-complexioned people of northern Europe, who were named by Huxley the Xanthochroii, and the Dark Caucasians or brown people, the Melanochroii of Huxley, who include the south Europeans, and some still darker people in Asia and Africa.

The numbers of the white, yellow, brown and black divisions of mankind, according to the returns for the last available year before the war, were—white or European race 520 million; Mongolian 620 million; brown 370 million; Negro 190 million—total 1,700 million. The coloured races are in the majority of more than 2 to 1. The advantages conferred on the Whites by their more efficient organization, better equipment, and command of transport and machinery should enable them to hold their own in any direct conflict, in spite of their inferior numbers. The danger to the white race comes from their dependence on trade with Asia and Africa which would be jeopardised by the restoration of the political conditions that held before those continents fell under European influence. The maintenance of European dominion lays a heavy burden on the white race, as it is responsible for the government of eight-ninths of the habitable land of the globe. One-third of the inhabitants of the world rule eight-ninths of it; the remaining two-thirds of the people control only one-ninth of the land.

This condition is modern. A thousand years ago the Whites held only part of Europe, for Spain was then ruled by the Moors and south-eastern Europe by Asiatics. Four centuries ago the white race had secured nearly all Europe; but the coloured races still ruled the rest of the world. The formula of Asia for the Asiatics and Africa for the Africans was then accepted, as well as America for the Red Indians. Even at the beginning of the last century only a small proportion of North America

and a few small settlements in Africa and Asia were occupied by the Whites. During the last century, and especially since the development of railway and steam navigation after 1840, the whole of America, all Africa except Abyssinia and Liberia, all Australia, and all Asia, with the exception of China, Japan, and Siam, have fallen under the control of European people. Since 1900 European influence has, however, suffered extensive reductions in Asia and Africa, which have advertised the relative decrease in the number of white people. During the past half-century the unprecedented increase in the white race has been exceeded by that of the coloured people. Increased disparity in numbers means, in a democratic age, an inevitable transfer of power; while the former prestige of the white man has been undermined by his own beneficent rule. Alike in war and peace the personal authority which the white man held in 1900 has undergone a momentous decline.

III. Geographical Principles.

Whether that movement is a temporary set-back or a permanent change in inter-racial relations is a problem on which Geography should afford the most reliable available guidance. If we accept the scope of Geography as the study of the earth with especial relation to man, its primary duty is to collate the results of other sciences which throw light on the major problems of human development. It should learn from physiology the effects of climate, altitude, and tropical sunshine on the different races of mankind; from biology what diseases are due to parasites and how infection may be prevented; it should find from agriculture the most profitable local crops and how to improve the food supply; it should discover from geology the nature and distribution of soils and the available supplies of minerals and mineral fuels; and it should seek from the ethnologist guidance as to the characteristics of the races who are competing in the struggle for existence. The geographer provided with this knowledge should endeavour to weigh evenly, free from race prejudice and political bias, and undisturbed by the fears of vested interests, the factors which control the distribution of mankind.

The ruling geographical principles as to the distribution of the three primary races may be summarized as follows: 1. The population must be scanty in the colder regions of the world owing to their long severe winter, and also in the dry deserts, except in those relatively small areas that can be watered by irrigation. 2. The tropical regions have hitherto been the home of the coloured races, while the white nations have been mainly restricted to the temperate zone. 3. When different races live side by side, the more primitive race, unless conditions be imposed on it fatal to its spirit, will outlive the other wherever the struggle for existence is keen.

From these principles two main inferences can be drawn. First, the frigid zones, the chief deserts, and the tropical plateaus above 12,000 ft. or so above sea level will always have a sparse population, and will long be left except for occasional commercial, mining, and industrial centres, to the most primitive tribes who have access to them, such as the Eskimo in North America, the Lapps in Europe, and various hardy, easily contented Mongols in Central Asia. Second, white colonists have no chance of per-

manently occupying land near the overcrowded parts of Asia or accessible to the fast multiplying Negroes of Africa. White merchants may find in these regions profitable trading centres and may for a time rule and administer them; but when white enterprise has subdued the land, built railways and utilized the rivers, the coloured man will oust the white from all but the few posts that require experts.

IV. Inter-racial Relations.

The relations of the white and coloured races living in the same land may be settled on any one of four lines—amalgamation by miscegenation; co-residence without fusion, and with complete social separation; the disfranchisement of the coloured population as State wards; or the segregation of the different races in separate countries or communities.

1. (*a*) *Racial Fusion.*—Amalgamation by complete racial fusion is often recommended as being either inevitable or desirable, or both. That plan is recommended by the improvements in stock and plants wrought by judicious interbreeding, and mankind may be expected to benefit by the same process. The great modern nations are of mixed origin, and their efficiency is doubtless due to the varied capacities inherited from their miscellaneous ancestors. Accordingly many authorities, such as Lord Olivier, anticipate the settlement of serious difficulties and the betterment of the human race by inter-racial fusion. Lord Olivier claims that mixed races are superior to those of simpler constitution. 'So far, then,' he says, 'as there survives in a mixed race the racial body of each of its parents, so far it is a superior human being, or rather, I would say, potentially a more competent vehicle of humanity' ('White Capital and Coloured Labour,' 1906, p. 22). H. G. Wells regards inter-racial prejudices as one of the worst of existing influences. 'I am convinced myself that there is no more evil thing in this present world than Race Prejudice; none at all, I write deliberately—it is the worst single thing in life now. It justifies and holds together more baseness, cruelty and abomination than any other sort of error in the world.' Its strength he considers renders it impossible for two races to live separately and in amity side by side. 'Racial differences,' he declared in an earlier statement, 'seem to me always to exasperate intercourse unless people have been elaborately trained to ignore them. Uneducated men are as bad as cattle in persecuting all that is different among themselves. The most miserable and disorderly countries of the world are the countries where two races, two inadequate cultures, keep a jarring, continuous separation' ('The Future in America,' 1906, p. 273).

The benefits of interbreeding, according to many authorities, are limited to parentage nearly akin, though in such cases the advantages are well marked, as exemplified in Canada. Intermarriage in mankind, it is urged, should be restricted to nearly related people. Herbert Spencer, in a famous letter that was not published until after his death, declared that the interbreeding of widely different types produces weak inferior offspring, with 'a chaotic constitution.' This view has been supported by modern students of Eugenics. Major Leonard Darwin, in a letter to the members of the recent Imperial Conference (1923), urged that 'theoretical reasons can be adduced for believing that interbreeding between widely divergent races may result in the production of types inferior to both parent stocks;

and that this would be the result of miscegenation is at all events a common belief.' Dr. J. A. Mjoen—who, according to Major Darwin, has made a long study of these questions and is 'an authority well worth considering'—after detailed study of the Mongolian-Caucasian hybrids in Norway, reports that the children of these Lapp-Norwegian unions are inferior physically and mentally. He concludes from his investigations that 'crossings between widely different races can lower the physical and mental level.' He urges 'Until we have more definite knowledge in the effects of race-crossings it will certainly be best to avoid crossings between widely different races' ('Eugenics Review,' 1922, vol. xiv, p. 39).

Professor Lundborg, of the Upsala Institution for the Study of Race Biology, has adopted the same conclusion. He deplores 'hasty race-mixture between nations who, from a race-biological point of view, stand too far apart.' He declares that 'a mixture between nations who, from a race-biological point of view, stand high and others containing lower race-elements, such as gipsies, Galicians, certain Russian tribes, etc., is certainly to be condemned.' Lord Bryce has twice asserted the same conclusion. According to this view mongrels (the offspring of different varieties) should be better than at least one of the parents, while hybrids (the offspring of different species or primary divisions of mankind) are necessarily inferior to both parents.

This doctrine cannot be regarded as established, but the strong intellectual aversion to such unions among the Teutonic people will doubtless prevent the adoption of race amalgamation between the Negro and the Whites in North America or of northern Europe. Opinion against this policy is hardening in the one country, the United States, where it might be expected to find most support. There, intermarriage between Whites and Negroes is illegal in most of the States, and opinion is against it on both sides, except in so far as it is welcomed by one section of Negroes who would tolerate it to overthrow the social restrictions imposed upon them.

1 (*b*) *Racial Fusion in South America.*—The system of Race Fusion has been followed in tropical South America, which is occupied mainly by a hybrid people. The intermarriage of Spaniards and Portuguese with Indians and Negroes has proceeded to such an extent that only a small uncertain proportion of the inhabitants are of pure European descent. The population of tropical South America is a mixed race with the exception of small clans in some of the cities of Ecuador and northern Peru. In most of South America there is said to be no more prejudice against the mixture of races in marriage than there is in Europe against that between different social classes. The limitation of marriage in South America is by class not by colour.

'Everything' in South America, said Bryce ('South America,' 1912, p. 565), 'points to a continuance of the process of race mixture.' 'Miscegenation,' says Garcia Calderon ('Latin America,' 1913, p. 356), 'is universal in South America between Iberian, Indian and African.' 'A single half-caste race,' he says (*ibid.*, p. 338), 'with here the Negro and there the Indian predominant over the conquering Spaniard, obtains from the Atlantic to the Pacific' and from Mexico to Patagonia. The predominance of the white race may be maintained in the southern parts, but most of South America seems destined to be the home of a hybrid Indo-Negro-

Iberian race. South America illustrates the results of miscegenation on a continental scale.

2 (*a*) *Co-resident Distinctness.*—The second available inter-racial development is by co-residence with the maintenance of racial distinctness. The greatest experiment with this policy is in progress in the United States. It is recommended there by leaders of both White and Negro opinion as the only solution of the inter-racial difficulties. Its most effective champion was the late Booker Washington, who is generally regarded as the greatest Negro whom America has yet produced. This policy aims at the association of the two races in work, but their complete social separation. According to Booker Washington's famous analogy the two races should be separated in life as completely as the fingers, but as fully united in work as the hand. This idea attracted support from various sides, as it offered a practical basis for development, and involved the renunciation by the Negro, at least for a time, of his claims for political and civil equality. This policy is dependent on the better education of the Negro. Booker Washington, amongst his other titles to fame, was a pioneer in agricultural education ; and his institution at Tuskegee has undoubtedly done much to raise the status of the American Negroes. He has, however, been violently condemned by many of his compatriots, owing to his asserted surrender of their claims. According to these critics the advance of this policy has been attended by the lowering of the civil and political status of the Negro, and the intensification of inter-racial feelings by raising the jealousy of the southern Whites at his improved educational and financial position.

The possibility of long continued associated distinctness by two intermingled races is contradicted, according to some authorities, by historic experience. Lord Bryce states that ' whoever examines the records of the past will find that the continued juxtaposition of two races has always been followed either by the disappearance of the weaker or by the intermixture of the two' (' The American Commonwealth,' 1911, vol. ii, p. 532). Professor Kelly Miller, of the Howard University, Washington, expresses his conviction ' that two races cannot live indefinitely side by side, under the same general régime, without ultimately fusing.' A. B. Hart, Professor of History at Harvard University, is more hopeful, and he cites the long continued co-existence of Hindu and Muslim in India, of Boers and Kaffirs in South Africa, and of English and Indians in North America ; but these cases give no more encouragement to the prospects of Negro-Caucasian association in America than do those of the Jews and Parsees.

2 (*b*) *The Position in the United States.*—Whether this policy is possible or not the testimony is overwhelming that the attempt to adopt it in the States has been attended by increasing tension and race bitterness, despite all the influences in its favour.

Under the auspices of a Commission for Inter-racial Co-operation 800 county inter-racial committees have been established. The two races have been uniting more often in educational and social work, both by informal association of neighbours, and by such organizations as the University Race Commission, the Southern Sociological Congress, the Rosenwald and Jeanes Foundations for the building of Negro Schools, the Phelps-Stokes Fund, the General Education Board and its Rockefeller Endowment, and by the munificent gifts of northern benefactors to

Hampton and Tuskegee. Moreover, the State Courts, by their decisions as to Pullman cars, have lessened the rigour of the regulations which separated white from coloured passengers on the railways ; and the Supreme Court of the United States, once regarded as unsympathetic to the Negro, has dismissed as unconstitutional some of the State laws that have been used to disfranchise him. Many circumstances favour the growth of more friendly feelings between the two races.

Nevertheless, the general testimony of writers on the United States during the past twenty years is that the position has been, and is, going steadily from bad to worse. ' The two races,' says Professor Hart (1910), ' are drifting away from each other and race relations are not improving.' A. H. Stone remarked in 1908 the increasing growth of race feeling among the Negroes. Lord Olivier in 1906 predicted that the policy which was and has been followed ' will doubtless in time bring about civil war.' William Archer, comparing the conditions in 1910 with those at the Atlanta Conference when Booker Washington put forward his co-residence policy, declares ' that the feeling between the races is worse.' W. P. Livingstone, a writer with West Indian experience, wrote in 1911 ('The Race Conflict,' pp. 13, 31) that the negro question 'remains, what it has been for a century, the darkest and most menacing cloud on the horizon of national life,' and that ' the situation is described as being worse to-day than at any time since 1865.'

' Any competent observer,' said Maurice Evans in 1915, ' must see in the South, as in South Africa, a gathering storm, which means ultimately not only industrial war, but industrial war *plus* racial conflict.'

The World War for a time appeared to improve the Negro position, owing to the labour shortage in the United States due to the stoppage of immigration from Europe and the urgent demand of the belligerents for munitions. But after peace the irritation of the Negroes at what they regarded as the systematic belittling of their war services and the friction due to increased contact in the cities led to serious race fights during 1919 at Washington, Chicago, Elaine, St. Louis, and Knoxville. These riots, with the determined defence offered by the Negroes, justify the insight of Livingstone's warning—' So gigantic does the problem appear, so difficult of peaceful solution, that the nation is helpless in face of it. It has become so subtly connected and interwoven with all the organic texture of the national existence that the people, as a whole, are afraid to make it a living question, not knowing what might be the result. There is an uneasy consciousness of the truth of the Southern warning, that the forces of the revolution, unspent and terrible, are ready at any moment to break out under sufficient provocation.'

3 (*a*) *Racial Segregation in the United States.*—So alarming does the position appear that three drastic solutions have been proposed based on the separation of the Negro community by political disfranchisement, exile, or segregation.

The first is the complete disfranchisement of the whole coloured population, including all with any appreciable proportion of Negro blood, and its tutelage under a special Board of guardians. The Negroes would have separate police and law courts, and separate schools in which the training would be mainly industrial. They would be wards of the State, and would elect representatives to their Board of protectors,

but would have no votes for the Federal or State Parliaments. A plan for treating permanently a seventh of the population as irresponsible helots would appear utterly inconsistent with the American Constitution, and impossible in modern conditions under any democratic constitution; and the Negroes, and especially the 'Near Whites' who are predominantly white by blood, would regard the status proposed for them as an intolerable degradation.

A second and still more drastic suggestion is the compulsory emigration of the whole Negro population to some such places as Hayti and Liberia. This solution was advocated by the distinguished American palæontologist, E. D. Cope, and it was favoured by Abraham Lincoln until he was persuaded that the whole of the North Atlantic shipping could not remove a sufficient number to keep up with the normal increase in the Negro population. The scheme has been often rejected as impossible on the grounds that the American Negroes are too numerous for transhipment, and that there is now no available room for them either in the West Indies or Africa. These difficulties would not be insuperable if the United States were determined to overcome them, and the Negroes were willing to go; for any such migration would obviously have to be spread through a considerable period and neither the cost nor lack of room for the emigrants would be beyond the power of so wealthy and resourceful a nation. But the project is not worth discussion here, as the political difficulties place it out of court.

An alternative segregation policy is that of collecting all the Negroes into one territory or State within the United States. That scheme might have been practicable in 1865 at the close of the Civil War; but as the areas suitable for Negro settlement which were then available have been occupied, this proposal appears as much a counsel of despair as that of transplantation to Africa and Hayti.

The only scheme of segregation within the sphere of practical politics is that for the assembly of the bulk of the Negroes in numerous scattered agricultural settlements where they would be withdrawn from close daily contact with the Whites, but would co-operate with the rest of their fellow-citizens in productive work. This agricultural ghetto policy would probably lessen inter-racial friction; but it would leave the Whites and Blacks in contact on so many surfaces that it might still lead to a slow process of fusion, and would not secure the permanent separation of the two races. The champion of this policy, Maurice Evans, indeed admits that it offers no final solution of the race problem in the United States. 'There is,' he says, 'no final solution possible, and the Negro will remain a problem for generations to come.'

3 (*b*) *The Probable Developments in the United States.*—If, therefore, of the three constructive policies absorption is rejected as it would make the United States a nation of octoroons or decaroons, permanent distinct co-citizenship be impossible, and segregation be impracticable, what development is possible? No single measure that could be imposed on the country by the Legislature appears to be available, but some solution may be reached by a process of drift. It is for the geographer to search for the factors that are likely to guide this drift.

One possible movement in the southern States is for much of the agricultural work to pass into the hands of immigrants from southern Europe, while the Negroes, through that restlessness which is the weakest

element in their character, tend to settle in the towns. Stone, a representative southerner, remarks that planters must seek more reliable labour than that of the Negro, who has already been replaced in tobacco cultivation in Kentucky. Booker Washington repeatedly called attention to the seriousness of the danger that the Negro would be driven from the skilled occupations. The recent agreement between Italy and Mexico for the settlement of 500,000 Italians in Mexico would provide an additional source for Italian inflow into the southern States. The feeling against inter-racial marriage is not so strong among the people of southern Europe as it is with the Teutons; hence extensive south-European immigration into the cotton districts may lead to their future occupation by a hybrid race similar to that of tropical South America. This process would render impossible the continued refusal of political and municipal rights to any citizen who has a trace of Negro blood. The coloured people would regain the suffrage, and the political development of the southern States on normal American lines would be impossible. If the Whites in the southern States be divided between Republicans and Democrats, the Negro vote would hold the balance of power; and owing to the considerable over-representation of the southern States in proportion to population, American politics might be determined by the Negro vote. Such a situation would be intolerable to the northern and western States. Hence, to avoid it, they might agree to the south-eastern States being formed into a group with a special measure of home rule in some departments of Federal jurisdiction.

This solution may take a century or more to develop; but the geographical considerations indicate it as the most probable issue from the Negro strength in the south-eastern States.

3 (*c*) *Segregation in South Africa.*—The system of inter-racial development by the segregation of the different elements in the population, though apparently impracticable in America, is one of the main issues in current South African politics.[1]

In Africa, the racial problem, as far as concerns the white and coloured races, is simple in most parts of the continent owing to the overwhelming majority of the coloured population. In Algeria and Tunis there has been an extensive settlement of south-Europeans, with whom the native Berbers are racially allied. Most of Africa is the home of Negroes, whose numbers are increasing faster than any other population in the world. European officials superintend most of the continent, but they and the European traders are few in number and are usually temporary sojourners. In a few localities, such as the Highlands of Kenya and of Nyasaland, the European colonies may be permanent; but even in these localities the bulk of the labour is supplied by Negroes, and much of the retail trade is conducted by Asiatics. The European colonists are a small dominant caste.

It is only in the Union of South Africa that the Whites are in sufficient numbers to form a considerable proportion in the population; but their future position, even in South Africa, is uncertain. There is no doubt of the suitability of the South African climate for Europeans. It has been the home of a large colony for more than a century, and the white

[1] The general election in South Africa, June 1924, shows the growing strength of the movement in favour of segregation.

Afrikander population is robust and efficient. But the maintenance of the white supremacy and even of a white Afrikander people is doubtful.

The population of the Union of South Africa in 1922 included 1,550,578 Whites and 5,504,580 coloured people; so the latter exceed the white by 3½ to 1 and are increasing the faster. The coloured race is in especial excess in Natal, where Indian coolies supply the bulk of the labour in agriculture, industry, and retail trade. In the rest of the Union the coloured excess is that of the Negro. The white dominion may be maintained either by a small oligarchy managing black labour; or by white workers remaining in sufficient number to keep control under a Parliamentary government.

The oligarchic plan, which is the ideal of the Capitalists, hopes for the development of South Africa on the lines adopted in India until recent years. This system seems, however, to have little more chance of permanence in South Africa than in India. The measures introduced to strengthen it led Booker Washington to condemn the native policy of parts of the British Empire as worse than that of the United States. The rule of South Africa by a minority of white men is threatened by the uprise of an active Negro party which, with the support of the Ethiopian Church, demands its full share in the government of the country. This aggressive South African party, largely inspired from the United States, is likely to increase in numbers and influence. It may be controlled so long as there remains in the country a large number of comfortably circumstanced white labourers. The fundamental difficulty in South Africa is, however, the position of the 'poor Whites'; they form a class who are apt to interbreed with the Negroes and increase the percentage of half-castes. Many of the poorer white men have been forced to take work which is despised by the better class of black labourers; and the spectre in South Africa is the steady replacement of white workers by Negroes and half-castes in the skilled occupations. One difference in South Africa between visits in 1893 and 1905 which impressed me as most significant was that all the farriery, which in the former year had been done by Whites, had passed to the Blacks. This process has gone so far that it threatens the existence of white labour in South Africa, and the Capitalist attitude to it has led to the alliance of the Nationalist and Labour Parties. One of the main issues in contemporary South African politics is the segregation of the Negroes and Asiatics. The Nationalists accept the conclusion that the white man cannot compete on equal terms with the natives and Asiatics in manual labour. The wages for white labour varies from 10s. to 30s. a day; while that of a native adult varies from 6s. to 30s. a month. The pay of native domestic servants is the same, with the addition of food. The white man in South Africa cannot live on the same wages as the blacks. As the Negro becomes better educated and enters trade after trade, his white competitor must withdraw or reduce his standard of living to a level which involves ultimate demoralization. Some of the supporters of the Capitalist party admit these facts and consider the fusion of the black and white races at the Cape inevitable.

The Nationalists reject this pessimistic conclusion. They recognize that it can only be avoided by maintaining the distinction between the two races, which are most liable to commingling among the poorer classes. The Nationalist programme therefore includes the policy of segregation, which is opposed by the Capitalists, on the ground that it is an anti-Capitalist

measure and would raise the cost of labour. General Hertzog and his party, however, insist that some policy of segregation affords the only chance of maintaining the position of the white man in South Africa. The segregation policy in defence of the Whites seems fully justified by its long adoption in the interest of the natives. Thus Basutoland and the Transkei Territory in the east of Cape Colony are reserved for the natives; no European can settle in them without the express permission of the Governor-General. As white labour is excluded from some parts of South Africa in the interest of the Negro, it would seem only fair that the Whites should have a corresponding advantage elsewhere and especially in districts which were practically unoccupied until the Europeans entered them. According to one plan of segregation the natives should have a privileged position throughout the eastern lowlands of Cape Colony and Natal, and in some eastern districts in the Orange Free State and the Transvaal; some parts of this division of the country should be reserved for the coloured races, and no white people allowed to acquire land or an interest in land within them. In compensation for this restriction certain occupations and some areas should be reserved for the Whites in the western parts of Cape Colony, of the Orange River Colony, and of the Transvaal. The principle of segregation was approved by the Natives Land Act of 1913, but it has obvious difficulties. The British residents in South Africa deplore much in the Afrikander Nationalist programme; but its policy of segregation appears to advance the only plan by which South Africa can be developed as the permanent home of a large population of the European race.

V. Tropical Colonization and the Future of Australia.

We have seen therefore that in North America the presence of the Negro has introduced problems of inscrutable perplexity; that in South America a mixed race is in firm possession; that in Africa as a whole the white man has no chance as a colonist; and that in South Africa his future depends on some complex measure of segregation. In Asia only in the north and north-west has the white man any prospect of permanent dominion. In contrast to these restrictions in Australia the fundamental problem is the possibility of the occupation of the whole continent by the European race.

When the chief inrush of immigrants into Australia occurred after 1850, the belief was almost universal that the natural home of the white man was in the temperate zones and that the torrid zone must be left to the coloured races. That policy was accordingly adopted by Australia and pursued for 50 years. The tropical districts were left open, with varying limitations, to Asiatic immigration. Few Asiatics, however, took advantage of this opportunity, though large numbers were eager to enter the cities and settlements in the south, where the European had done the pioneer work. In the north the Asiatics were a hindrance, as they were too few to help materially, and they were sufficient to discourage the entrance of white artisans.

In 1901 Australia, on Federation, found itself faced by two problems—the empty north which the open-to-Asia policy had not filled, and the disturbing effect of indentured coolies on white labour. The policy of excluding coloured people and working the northern plantations with white

labour was declared to be a physical and physiological impossibility. According to Mr. Benjamin Kidd ('Control of the Tropics,' 1898, p. 48), 'the attempt to acclimatize the white man in the Tropics must be recognized to be a blunder of the first magnitude. All experiments based upon the idea are mere idle and empty enterprises foredoomed to failure.' Lord Olivier's opinion is that 'Tropical countries are not suited for settlement by Whites. Europeans cannot labour and bring up families there.' Mr. R. W. Hornabrook declares that to send Whites from Europe to Tropical Australia 'is nothing short of a crime—it is worse, it will be murder.'

In 1907, in opposition to this traditional view, I remarked ('Australasia,' I., p. 15) that 'medical authorities on tropical climates seem now, however, to be coming to the opinion that this view is a popular prejudice which does not rest on an adequate foundation.' The evidence to that effect had been stated in a remarkable paper by Dr. L. W. Sambon, and endorsed by the late Sir Patrick Manson, and has been supported by the general trend of medical opinion during the past seventeen years. Thus a leading article in the 'Journal of Tropical Medicine' (15 January, 1919, pp. 15-16) proclaims 'Disease, not climate, the Enemy . . . If there is one thing which the study of tropical diseases has shown us, it is that disease, and not the climate, is the cause of this crippling of trade, of the necessity for frequent changes "home," involving expense and the employment of a large permanent staff to fill the gaps caused by sickness, and therefore lessening of profits. The legends, a "bad climate," an "unhealthy climate," are well-nigh expunged from tropical literature. All medical men familiar with the Tropics are cognizant of the fact that disease, and, what is more, preventable disease, is the cause of the bad name associated with any particular region of the Tropics.'

The general distribution of mankind is in such close agreement with the rule that the white race has settled in the temperate regions and left the tropics to the coloured races, that any policy inconsistent with that arrangement must be prepared to encounter a strong prepossession to the contrary. Nevertheless, that rule is inconsistent with so many facts that it is not a safe basis for a national policy. In America, for example, the whole continent, except for the Eskimo in the north, was occupied by dark coloured Mongolian tribes, in which, according to Flower and Lydekker ('Mammals,' 1891, p. 752), 'the colour of the skin, notwithstanding the enormous difference of the climate under which many members of the group exist, varies but little.' The most northerly part of Europe is occupied by a coloured race, the Lapps. In Africa the darkness of the skin does not always vary in accordance with distance from the Equator.

1.—Supposed Unfavourable Factors in Tropical Climate.

(*A*) *Heat.*—The belief in the unsuitability of the tropics for the white man rests on several considerations. Most importance is naturally attributed to the heat, as that is the essential difference between the tropical and other zones. Intense heat is regarded as injurious to people not protected by a dark skin. That view overlooks the automatic process by which the living body adjusts itself to temperatures even higher than occur in any climate on earth, and that would quickly cook it, if dead.

During some experiments by Sir Charles Blagden in 1774, Sir Joseph Banks remained in a room for seven minutes at a temperature of 211° ; and Blagden subsequently stayed at the temperature of 260°, while eggs were roasted hard and beefsteaks cooked in a few minutes. White men work in furnaces and bakeries at 600° F., and if they can survive such temperatures even for short spells, they should be able to withstand the hottest climate on earth.

That heat is not the dangerous factor in the tropics is obvious from the well-known fact that the hottest areas are often the healthiest. Agra is hotter and healthier than Bombay, and the summer heat of Colorado is fiercer than that in the less healthy Mississippi Valley.

(*b*) *Moist Heat.*—As dry heat affords no explanation of the high mortality of some tropical localities, appeal was made to moist heat, and to the combination of heat and moisture marked by a high wet bulb temperature. At any temperature above blood heat the body is cooled only by the evaporation of perspiration, which does not take place in air saturated with moisture. Hence in the Townsville experiments ('Proc. R. Soc.,' B.xci, 1920, p. 121), a man placed in a room in which the wet bulb temperature rose from 98° to 102°, fainted in forty minutes. In a hot locality a dose of atropin, which suppresses perspiration, may be quickly fatal.

A wet bulb temperature higher than blood heat would be fatal to men, white or black ; but no earthly climate has such temperatures. It was at first suggested that the limit of human activity was the wet bulb temperature of 73°. I have previously quoted [2] well authenticated records of miners working for four-hour spells for months at the wet bulb temperature of 80° to 90° in Hongkong, the Straits Settlements, Beaufort in Borneo, and Ocean Island in the Pacific. At all these places people, both white and coloured, survive these conditions. Hence the limit has been gradually raised and it is recognized that men can withstand wet bulb temperatures of 85°, though the power of work under such conditions is necessarily greatly reduced. The highest wet bulb temperature mentioned in Dr. Griffith Taylor's record at Port Darwin is 81°. The wet bulb data for North Australia are scanty ; but there seems no reason to expect that any considerable areas have a more uncomfortable climate than Calcutta, to which Dr. Taylor compares the worst localities of tropical Australia. Calcutta is one of the healthiest cities in India, and has a large and vigorous European population, many of whom spend there the whole year.

Moist heat is trying and must be considered in judging climates from the standard of comfort and personal efficiency. The investigation of wet bulb temperatures—the significance of which was shown by Dr. J. S. Haldane, has been developed in reference to the textile industries by Dr. Leonard Hill and Dr. Boycott, to mining by Sir John Cadman, and to the conditions of tropical Australia by the work of Professor Osborne and has been illustrated by the ingenious climographs of Dr. G. Taylor—has yielded results of high practical value. But the wet bulb isotherm does not delimit the areas where the white man may live and work, and does not

[2] 'The Wet Bulb Thermometer and Tropical Colonization.' *Journ. Scott. Meteor. Soc.*, ser. 3, vol. xvi, 1912, pp. 3–9.

really affect the question of white *versus* black colonization, as there does not seem to be any reason to believe that black men could withstand a higher wet bulb temperature than white men. In answer to an inquiry on this question, Dr. J. S. Haldane replied that his impression on the contrary was that 'white men can usually stand more heat than black men,' and he reported the information given him that in places like the Red Sea the Clyde stokers stand the heat better than the Lascars, 'and, in fact, have constantly to carry the latter out and lay them on deck to cool.' Dr. C. J. Martin also informs me that there seems no physiological reason why the conditions indicated by a high wet bulb temperature should be more adverse to the white man than to the coloured races.

(*c*) *Monotony in Temperature.*—Another temperature factor that has been appealed to is that depressing equability of temperature which occurs on some tropical coasts. Excessive monotony in the weather is no doubt depressing and temperature changes have a stimulating beneficial effect. Extremes of cold and heat are still more inconvenient and trying, and a moderate equability is often advertised as an attractive feature in a climate. The equability of the oceanic climate is recognized as most favourable for many conditions of health. The areas over which extreme uniformity of temperature prevails throughout the year are, however, so restricted that this factor does not affect the problem of tropical settlement as a whole. With the exception of low tropical islands, places with monotonously equable climates are in positions whence a change may be secured by a visit to some neighbouring hill country.

(*d*) *Actinic Rays.*—A fourth factor to which much importance has been attached in connection with the tropical climate is the effect of the chemical rays of the sun. Great importance was once attached to the pernicious influence of the ultra-violet chemical rays of the sun on persons not protected by a dark skin. Residents in the tropics were therefore advised to line their clothes with orange-coloured fabrics to shield themselves from the chemically active rays. These views reached their extreme in the writings of Surgeon-Major C. E. Woodruff in 1905 on the 'Effects of Tropical Light on White Men.' Woodruff held that the actinic rays of the sun are so inimical to the white man that they inhibit his permanent settlement within 45° of the Equator. He therefore regarded the tip of Patagonia as the only area in the Southern Hemisphere fit for white occupation. The temporary stagnancy of the population of Australia after the droughts of 1900-1902 he regarded as evidence that the native-born white Australian and delicate New Zealander were wasting away through physical decay due to the enfeebling sunshine, just as the health of American and European children was being ruined by the 'daft' practice, as he called it, of flooding schoolrooms and nurseries with streams of light. Woodruff's conclusions have naturally been disregarded.

Any deleterious effects of the chemical rays of the sun may be avoided by the use of appropriate clothes, and physical considerations suggest that a black skin should afford less protection than a white skin. Any injury that may be wrought by powerful sunshine, according to Aron's work in the Philippines, is due to the heat rays at the red end of the spectrum and not to the chemical rays. The modern lauded system of heliotherapy is based on the belief that strong sunshine is a powerful curative agency.

(e) *Miscellaneous Factors.*—The four previously considered factors have the advantage that they can be readily understood and tested ; but as they have failed to provide any basis for the unsuitability of the tropics for the white man, the appeal has been shifted to a complex of tropical influences, including a rise of body temperature, the lessened activity of lung and kidney, and nervous disturbances. Dirt and disease and carelessly prepared food are also mentioned, though they are due to human agencies. The physiological effects of the tropical climate in this indictment are contradicted by high authorities. The rise in body temperature is emphatically denied amongst others by Breinl and Young from observations in Queensland, and by Chamberlain on the basis of extensive observations on American soldiers in the Philippines. A slight rise may occur in passing from the temperate regions to the tropics, but it is soon recovered ; and Shaklee reports from his experiments on monkeys at Manila that ' the healthy white men may be readily acclimatized to the conditions named—that is, to the tropical climate at its worst.' Shaklee adds that the most important factor in acclimatization is diet.

The asserted ill-effects of the tropics on respiration appear to have no more solid basis. Professor Osborne found at Melbourne that the rate of respiration was increased on the hottest days, and his observations agree with those of Chamberlain in Manila. So far from the tropical conditions being injurious to the kidneys, it is asserted, as by Dr. A. B. Balfour, that there is less trouble with that organ in tropical than in temperate climates. The apparently inconsistent observations on the action of the kidneys between various tropical localities and people, may be explained by differences in diet.

The remaining charges against the tropical climate are insignificant, or not based on climatic elements, or are indefinite. Some of the alleged factors are trivial, such as the liability to various skin diseases owing to a change in the skin reaction ; for if the white man allows himself to be kept out of any country by such a cause he does not deserve to get in. The hygienic troubles due to association with an insanitary people are sometimes adduced ; but they are not an element in climate and would not operate in a land reserved for white people. The remaining factors rest on ill-defined nervous ailments which are more likely to be due to domestic difficulties than to climate. These nervous troubles fall mainly on the women who have the strain of disciplining native servants into conformity with British ways. Nervous disorders are said to be worst in hot, dry, dusty regions which in the tropics are generally regarded as the most healthy, except to those whose constitutions require a moist atmosphere.

2.—Medical Opinion.

Medical opinion has gone far towards the general adoption of the conclusion that there is nothing in climate to prohibit the white man from settling in the tropics.

As an example of a recent authoritative verdict may be quoted the report of a sub-committee appointed in 1914 by the Australian Medical Congress to investigate the medical aspects of tropical settlement. After extensive inquiries, the comparison of the blood of children born and bred in the tropics with those of the temperate regions, and other evidence, the

sub-committee reported in 1920 as follows : 'After mature consideration of these and other sources of information embodying the results of long and varied professional experience and observation in the Australian Tropics, the sub-committee is unable to find anything pointing to the existence of inherent or insuperable obstacles in the way of the permanent occupation of Tropical Australia by a healthy indigenous white race. They consider that the whole question of successful development and settlement of Tropical Australia by white races is fundamentally a question of applied public health in the modern sense . . . They consider that the absence of semi-civilized coloured peoples in Northern Australia simplifies the problem very greatly.'

3.—Improvements by Public Sanitation.

The trend of medical opinion to the view that there is no physiological reason why the white race should not inhabit the tropics may lead to a change similar to that regarding some localities in the temperate zones, which were formerly regarded as death-traps and are now popular health resorts. The island of Walcheren, on the coast of one of the most densely peopled countries in Europe and only thirty miles from so fashionable a watering-place as Ostend, had a century and a quarter ago one of the most deadly climates in Europe. The largest army which had ever left the British islands landed there in 1809. Napoleon did not think it worth powder and shot. 'Only keep them in check,' was his order, 'and the bad air and fevers peculiar to the country will soon destroy the army.' Napoleon's judgment was justified. The force of 70,000 men disembarked on July 31 and August 1. By October 10, according to Sir Ranald Martin, 142 per thousand were dead of disease, and 587 per thousand were ill.

Algeria is now a trusted sanatorium. Yet disease annually swept away 7 per cent. of the French army that conquered it. Sir A. M. Tulloch remarked that if the French Government had realized the significance of that mortality 'it would never have entered on the wild speculation of cultivating the soil of Africa by Europeans, nor have wasted a hundred millions sterling with no other result than the loss of 100,000 men, who have fallen victims to the climate of that country.' The same change of view has taken place in reference to some tropical localities. The deadliness of the Spanish Main to our armies was described by Samuel Johnson. 'The attack on Cartagena,' he said, 'is yet remembered, where the Spaniards from the ramparts saw their invaders destroyed by the hostility of the elements ; poisoned by the air, and crippled by the dews ; where every hour swept away battalions ; and in the three days that passed between the descent and re-embarkation half an army perished. In the last war the Havanna was taken, at what expense is too well remembered. May my country be never cursed with such another conquest.' Yet Havanna, under American administration, has become one of the healthiest cities in the world.

Sir John Moore, when Governor of St. Lucia (1796), wrote home that it is not the climate that kills, but mismanagement. His insight has been demonstrated in the same region. The French attempt to build the Panama Canal was defeated by disease. Discovery of its nature enabled

the late Surgeon-General Gorgas to secure for the 10,000 men, women and children in the canal construction camps, in spite of the high humid heat, as good health as they would have had in the United States. Gorgas claimed that the results at Panama ' will be generally received as a demonstration that the white man can live and thrive in the tropics.' Gorgas realized that the results for the future are even more momentous. He predicted that as ' the amount of wealth which can be produced in the tropics for a given amount of labour is so much larger than that which can be produced in the temperate zone by the same amount of labour, that the attraction for the white man to emigrate to the tropics will be very great when it is appreciated that he can be made safe as to his health conditions at small expense. When the great valleys of the Amazon and of the Congo are occupied by a white population more food will be produced in these regions than is now produced in all the rest of the inhabited world.'

4.—Old-established European Settlements in the Tropics.

Similar improvements are in progress elsewhere and explain why some white colonies have existed for long periods in the tropics without physical deterioration.

Two distinguished authorities on Equatorial South America—A. Russel Wallace and Richard Spruce—agree that under the Equator in Ecuador and northern Peru there are many Spaniards whose ancestors have lived there for centuries. Spruce says that some of the Spanish families at Guayaquil (lat. 2°13′S.) are pure in race, and have maintained their physical fitness after centuries of residence under the Equator. In the West Indies there are various old-established European colonies. The island of Saba (17°38′N.) was occupied by the Dutch in 1644. The descendants of the original settlers still occupy it and, apart from some effects of in-breeding, are reported to be healthy and vigorous and incontestably pure in race. Some of the German colonies in Brazil are within the tropics, and though established as early as 1847 the settlers are in good physical condition ; at Santa Katharina, in a low-lying part of the coast just south of the tropics, the 85,000 Germans are reported to have better health than the natives.

The European settlement in the tropics in the small island of Kissa, off Timor, is especially remarkable for its long survival, despite its small numbers and unfavourable circumstances. Eight Dutch soldiers and their wives were landed on Kissa in 1665 to hold it against the Portuguese. They were forgotten, but they established themselves, and their descendants now number over 300. The Admiralty Pilot describes the island as unhealthy and feverish. Nevertheless, the Dutch colony is said to be healthy, and many of its members have fair hair, blue eyes and blonde complexions. They retain the names of the original settlers, but they have lost their Dutch language and religion, and have adopted many native ways of life. A Dutch missionary, Rinnooij, has referred to the settlers as mestizos, *i.e.* half-castes, and states that the soldiers took wives from the daughters of the land. His statements are quite inconsistent with the later and more detailed account by Professor Macmillan Brown. If the women of the colony had always been natives of Kissa, the survival of the light hair, eye, and skin appears inexplicable. Hence, though Macmillan Brown may have underrated the Malay infusion, it

appears probable that this colony is mainly of Dutch stock, and has kept its physical characteristics undamaged by the two-and-a-half centuries of residence only eight degrees from the Equator.

Many cases of the decadence or extinction of ill-placed European colonies in the tropics are of course known, such as the Bahamas, as described by Professor Ellsworth Huntington. Such misfortunes have been regarded as evidence of the inevitably injurious effect of the tropical climate on white men. But if white colonies have maintained good health in the tropics, the failures are not caused by climate alone.

5.—The Development of Tropical Australia.

The experience of colonization in tropical Australia is limited to about seventy years; but it affords no ground for the expectation that the ultimate effects on the white race will be detrimental.

(*a*) *Vital Statistics in Queensland.*—In Queensland, most of which is tropical, the death-rate is lower than in any European country and is lower than in most of extra-tropical Australia. In the six years 1915-21, according to the statistics in the Australian Year-book (No. 15, 1922, p. 99), the crude death-rate in Queensland was the lowest in the six Australian States for one year, and fourth of the six States in three years, and the fifth in three; it was not once the highest. In the same six years the infantile death-rate was lowest in Queensland in three years, and the second lowest in two others. According to the same authority, by Index of Mortality (*i.e.* the death-rate in proportion to the ages of the community), Queensland was in 1921 the second State in order of merit, being inferior only by ·03 to New South Wales, the State most favoured in this respect.

The physical vigour of the Queenslander is shown by his athletic prowess, and by the low rejection-rate of recruits from that State for the Citizen Army. The longevity in Queensland may be judged by the experience of the life assurance offices. It has often been asserted that assurance rates show that tropical climates are unhealthy. Yet the chief actuary for the greatest Australian assurance company, the Australian Mutual Provident Society, reported to the Committee of the Australian Medical Congress, 'I have no hesitation in saying that as far as we know at present there is no need for life assurance offices to treat proponents who live in North Queensland differently from proponents who live in other parts of Australia.'

Physical and mental degeneration in a people living under unfavourable conditions would probably be most readily observed in the children. To use this clue I asked the Queensland Education Department whether its inspectors had noticed any unfavourable symptoms among the children in the most tropical of its northern schools. The Department replied that on the contrary its schools at Cairns and Cooktown, two of the most northern towns, are exceptionally efficient and one of them is sometimes the leading school in the State.

(*b*) *Northern Territory.*—The great success of Queensland, although more than half the State is within the tropics, renders the more striking the failure of the adjacent Northern Territory of Australia, of which the records are disappointing. Agriculture has declined; the Government demonstration farms have been reduced to native reserves; the meat

works have been closed; the population has fallen in numbers; and mining production has become insignificant. The present state of the Territory has been adduced as evidence of the futility of trying to develop a tropical land by white labour. Its failure was not, however, due to the White Australia policy, which was introduced after the failure was complete, but to geographical disadvantages not yet surmounted. The Territory, before 1901, was open to Asiatic immigration, but the hope that it would be adequately peopled from Asia was not fulfilled. Its population was largest in 1888, and then it was only 7,533. The Chinese were most numerous during the construction of the Pine Creek Railway in 1887-8; their numbers were 4,141 in 1890, and fell to 2,928 in 1900, and to 1,387 in 1910. High expectations had been formed of the Northern Territory from its tropical position, and it was hoped to become an Eldorado as an Australian Java. It was fondly called 'the Land of the Dawning,' and described as containing limitless areas of, for some purposes, the best land in the world. Searcy, for example, declared that it includes 'land equal in size to the islands of Java and Madura, suitable for any sort of tropical agriculture.'

Careful comparison with Java would, however, have served as a warning that easy prosperity was impossible. Java has been a densely-peopled, highly-cultivated island, with an advanced indigenous civilization since prehistoric times. The Northern Territory of Australia has been throughout the same period practically an unoccupied deserted waste. Java has rich widespread soils and a convenient rainfall. The Northern Territory has in the main poor soils, and its rain all falls during five, and most of it during three months, leaving the land parched and scorched for seven months every year. The water from the wells is alkaline and the supply too small for extensive irrigation, while land irrigated with it is soon rendered sterile.

Poorness of soil, unsuitable distribution of rainfall, and inaccessibility of position explain the backwardness of the Northern Territory. Dr. Jensen, the former Government Geologist for the Territory, describes the agricultural resources as 'circumscribed,' the rich patches of lowland soil being 'so wretchedly small and so few,' while the larger areas are situated where they could 'only be successfully cultivated by the installation of great irrigation schemes, which are not warranted, while equally good areas are available in other States with better climate, facilities, and markets.' Great hopes are based on cotton, despite Dr. Jensen's pessimism regarding it. Its profitable cultivation appears dependent upon the establishment of a protected cotton manufacture in Australia, which would secure a market for the crop at a price that would pay for the high cost of picking.

The remedy for the failure of the Northern Territory lies not in another attempt with Asiatics, but in the removal of the isolation of the Territory. Two routes for railway connection are available—the completion of the Mid-Continental Line to South Australia, or the construction of a line past the Gulf of Carpentaria to Queensland. The route to Adelaide appears the more promising, as it would connect two areas so different that they would be complementary and not competitive; whereas the railway to Queensland would run through one climatic zone and would connect districts which yield the same products. No special advantage would accrue to

Queensland from opening another tropical area; whereas a railway to Adelaide would connect localities in different climatic belts. While the only access to Port Darwin from the capital cities of Australia is by a voyage of 3,000 or 4,000 miles remote from either of the main steamer routes to Australia, the satisfactory development of the Northern Territory will be impossible.

(c) *Queensland and the Sugar Industry.*—Queensland in contrast to the Northern Territory has made firm progress; the population has continued to increase; and though at first coloured labour was introduced, the proportion of the Asiatic population in 1911 was only 1·47 per cent., and of the Polynesian only ·29 per cent.

The numbers of coloured labourers in Queensland were too small seriously to affect the population, but they were sufficient to be a constant irritant and source of uncertainty in the local labour market. This trouble led, in 1900, to the prohibition of indentured coolie labour throughout Australia. This decision was supported by the great majority of the Queensland people in spite of the most emphatic warnings of disaster.

Some of the sugar estates are in localities with extreme tropical climates; and the Queensland Chambers of Commerce, members of Parliament, Farmers' Associations, and bishops, declared that sugar could not be grown by white labour. The difficulty was said to be an absolute physical impossibility and not merely economic, so that the stoppage of Kanaka labour meant the certain death of the Australian sugar industry. At that time the sugar plantations were not prosperous, and exclusion of the Kanakas was supported on the ground that so struggling and unprofitable a branch of agriculture had better die rather than upset the policy of the whole continent.

The Bill for the exclusion of the South Sea islanders was therefore enacted and the sugar industry left dependent on white labour. In spite, however, of the confident predictions of the experts and their friends the industry has gone on and been more successful than when run by coloured labour.[3] The returns of the industry are irregular. In some seasons the yield is good, as in the record year 1917-18, and more land is planted. An unfavourable planting season reduces the area under cultivation and the yields in the second and third years later. Comparisons of single years are uncertain; but the following table shows that the areas under cane and the quantity of sugar produced have increased greatly since the industry became dependent on white labour.

[3] I gave an account of the progress of white labour on the plantations up to 1908, after a visit to four of the chief sugar-producing districts, in the *Nineteenth Century*, February 1910, pp. 368–380; and in the *Proc. R. Phil. Soc.*, Glasgow, vol. xliii, 1912, pp. 182–194.

QUEENSLAND SUGAR PRODUCTION.

—	Acreage	Cane, Tons	Sugar, Tons
1900–1 . . .	108,535	848,328	92,554
1906–10 . . .	134,107	1,415,745	152,259
1910–11 . . .	141,779	1,840,447	210,756
1916–17 . . .	167,221	1,579,514	176,973
1917–18 . . .	175,762	2,704,211	307,714
1918–19 . . .	160,534	1,674,829	189,978
1919–20 . . .	148,469	1,258,760	162,136
1920–21 . . .	162,619	1,339,455	167,401

[The sugar yield for 1922 is reported as 288,000 tons.]

It may be said that the increase in output and area ought to have been larger, but it should be understood that the Queensland sugar industry is not situated under specially favourable natural circumstances, as the land suitable for sugar occurs in relatively small isolated areas. Hence, the cane has to be treated at forty scattered mills, and the work cannot be done as economically as if concentrated in a few places.

The Australian adoption of white labour for its sugar plantations has been the greatest contribution yet made to the practical solution of the problem whether the white man can do agricultural work in the tropics. The experiment shows that white labour can be employed successfully in such an ultra-tropical industry as sugar cultivation in even the ultra-tropical climate of the Queensland coastlands, provided the settlers are protected from infectious disease and from the competition of people with lower standards of life.

6.—RATE OF PROGRESS AND THE DRAWBACKS OF THE TROPICAL CLIMATE.

The results of the Australian decision in 1901 to discard coloured labour have shown that the daring policy then begun is practicable ; but it may render development slow and costly. The slowness of the progress may be amply compensated by its sureness in the end. Some American authorities on migration (*cf.* H. P. Fairchild, 'Immigration,' 1923, pp. 215–225, 342) maintain that immigration during the past half-century into America has not added to the total population, as it has lowered the birth-rate of the older American stock, and merely substituted a very large foreign for a native element that would otherwise have come into being. An immediate increase caused by the introduction of a large number of Asiatics might mean a reduction in the European proportion in the Australian race, with in the end no increase in the total population.

The conclusion that white settlement of the tropics is possible should not lead to the drawbacks of a tropical climate being overlooked. The conditions where the wet-bulb temperatures are high are uncomfortable and unfavourable to mental and physical activity. People who are not keenly interested in their work should avoid the tropics. Ellsworth Huntington in a valuable series of works has called attention to many facts which show the dependence of Western civilization on the stimulating nature of the temperate climate, for the frequent changes in temperature and wind are conducive to alertness and general efficiency.

The enervating effect of the tropical climate is no doubt counterbalanced by various compensations. Man needs less in food, fuel, clothing, and housing, while the same amount of exertion will produce a more luxuriant

and valuable crop. The supremely fertile tropical regions have, however, usually a hot muggy climate, which is not attractive to Europeans while areas with less trying conditions are available. Northern Australia, even if it were not hampered by a high proportion of poor land, would naturally develop slowly, just as in Canada the Northern Territory and the rocky backwoods have lagged behind the St. Lawrence basin and the rich-soiled western plains.

The natural development of tropical Australia would be by overflow from the south when that part of the continent is more adequately peopled. Progress could be best aided by opening routes to tempt those with pioneering instincts to wander northward. This process may be considered too slow by those who consider the immediate occupation of tropical Australia a political necessity in order to prevent its annexation by some Asiatic Power; but the alarms based on Asiatic designs against Australia ignore the vast empty areas in Asia, the rich lands that could be more easily acquired in the Eastern Archipelago, and the persistence with which the people of south-eastern Asia have shunned areas in their own continent under geographical conditions corresponding to those of most of tropical Australia.

7.—Conclusion.

The conclusion that the white man is not physiologically disqualified from manual labour in the tropics and may colonize any part of Australia simplifies inter-racial problems, as it provides an additional outlet and spacious home for the European race.

The preceding survey of the position where the three main races meet in intimate association indicates that the world will have a happier and brighter future if it can avoid the co-residence in mass of members of the different primary divisions of mankind. Individual association and contact should secure for each race the benefit of the intellectual, artistic, and moral talents of the others; while industrial co-operation should aid each nation to make the best use of the land in its care.

The world has reached its present position by the help of each of its three great races, and it still needs the special qualities of each of them. The contemplative Asiatic founded all the chief religions, the ethical basis of civilization. The artistic Negro probably gave the world the gift of iron, the material basis of civilization. The administrative genius of the European race has organized the brain power of the world to its most original and constructive efforts. The affectionate, emotional Negro, the docile, diligent Asiatic, and the inventive, enterprising European do not, however, work at their best when associated in mass. That association is attended with serious difficulties; for race amalgamation, which is the natural sequel, is abhorrent to many nations, and the intermarriage of widely different breeds, according to many authorities, produces inferior offspring. The policy of co-residence with racial integrity has failed to secure harmonious progress in North America and South Africa. The development of the best qualities of the three races requires their separate existence as a whole, with opportunities for individual association and co-operation.

In view of the inter-racial difficulties that have developed wherever the races are intermingled, Australia will throw away a unique opportunity if it fails to make a patient effort to secure the whole continent as the home of the white race.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

A RETROSPECT OF FREE TRADE DOCTRINE.

ADDRESS BY

SIR WILLIAM ASHLEY, PH.D., M.COM., M.A.,

PRESIDENT OF THE SECTION.

A MAN would be singularly insensible who could stand in this place without emotion after an absence from Toronto of well-nigh a third of a century; and dead indeed to feeling when, across that long interval, he could look back to four years of such experience as fell to me in this City and Dominion between 1888 and 1892. The place where a man first makes a settled home; where he first knows the joys and anxieties of family life, where he meets with abundant daily kindness in unfamiliar surroundings, can never cease to be affectionately remembered. And when it is the place where, young and English as he was, he was entrusted by Canadians with the task of organising a new department in a University already important and destined to be great, and in a Dominion where he was the first Professor of Political Economy, his satisfaction at finding himself unexpectedly in the scene of his early endeavours can be readily understood. And how much has happened since then! The material development of the Dominion will be the theme of many papers in this and other sections of the Association. On the academic side one notes that where there were two considerable universities there are now half a dozen or more; that where there was one professorial economist there are now a score. I remember with what inward trepidation I confronted my duties. It is fortunate that in youth, when one wants it most, one has a better conceit of oneself than in maturer years. But this little credit I can take to myself: even in the earliest days of my association with young men and women in the University of Toronto, I was never so blind as not to realise that here, in Canada, was the future home of a great nationality, with its own vigorous patriotism and its own confident outlook on the future.

Political Economy is now old enough to have reached the stage of retrospect. I shall take advantage of this circumstance, and I shall ask you to consider with me a well-rounded body of economic ideas during a well-marked period. The body of ideas shall be the general English doctrine of International Free Trade. And the period shall be the century approximately which followed the publication of the 'Wealth of Nations.' It is well marked in economic literature; for it covers the time which elapsed before the new developments made themselves felt which are associated with the names of Jevons and Cliffe Leslie. And it is well marked externally; for it came to an end before England had lost the commercial supremacy due to its early utilisation of coal and iron, and before English agriculture had

begun to be seriously affected by the cheap grain of the new countries. The doctrine was imposing by its simplicity and symmetry. It consisted of a few easily intelligible propositions, following readily one upon the other, and so sweeping in their range, and so optimistic in their implications, that they dwarfed all cautious exceptions and qualifications. No great English economist indeed—neither Adam Smith, nor Malthus, nor Ricardo, nor John Stuart Mill—was, in fact, an out-and-out free trader so far as practical application was concerned. Still less were they resolute non-interventionists over the whole range of economic life; for entirely consistent and unlimited *laissez-faire* we should have to go to their more severely logical French contemporaries. But they based themselves on certain general principles, and they drew from them general conclusions which practical politicians could easily employ to justify an absoluteness of policy from which they shrank themselves; they were reverenced as spiritual masters, whose occasional aberrations must be lamented or disregarded.

I shall endeavour first to set forth the doctrine in a number of brief propositions; then to make some observations under each head. The several theses will not be found quite so consecutively stated in any of the authoritative writings, and I pursue this method partly for ease of subsequent reference. But it will be agreed, I expect, that they fairly represent the general structure of thought on which rested the whole edifice.

These, then, are the propositions:

1. That Nature is beneficent. By 'Nature' is meant, in this connection, the operation of the unpremeditated instincts, desires, passions of individual men and women. Any restriction of this operation by an authority outside the individual is 'artificial,' and therefore bad. Nature, so understood, is the scheme of things created by God. And since God, with infinite wisdom, has established this mechanism for the fulfilment of His purposes, Nature is, as it were, His Vicegerent, and the 'laws' of its action are 'providential.' But theistic language may be dropped, and the theistic conception even repudiated. And then 'Nature' remains as self-directed, and beneficent of itself; and the reverence with which it is regarded amounts in effect to deification.

This does not mean that every particular action dictated by a 'natural' passion is, considered in itself, morally commendable: it may even be 'shocking' to the moral sense. But the 'natural' impulses work out on the whole for good, with only such a minimum amount of evil as is involved in the execution of the whole design. The wisdom of God is displayed in the folly of men: by an Invisible Hand they are led to promote salutary results which are no part of their intention.

2. That individual Freedom or Liberty is in itself a good thing. This is a corollary from, or rather, only another expression for, the preceding proposition. For by 'freedom' or 'liberty' is meant the right to pursue unchecked the instincts or passions implanted by Nature. It is true that this liberty must respect the like liberty of others; and reflection on what is involved in this qualification might suggest some doubt as to the validity of the proposition it qualifies. But this line of thought was left for subsequent generations.

So long as the purpose of the social union is conceived of as the enabling of the individual to follow his 'natural' desires, their pursuit is regarded

as a 'natural right.' Violations of natural liberty are therefore inherently 'unjust.' But the conception of inherent individual rights may be repudiated; and then interference may be condemned simply on the ground that it is impolitic from the point of view of social utility. In any case the presumption is held to be on the side of 'liberty.' The term, first 'natural liberty' and then 'liberty' or 'freedom' without the adjective, could thus be used, without formal argument, as bringing with it a whole atmosphere of commendation; while 'interference' or 'artificial' brought at once, and without attempt at formal proof, a whole atmosphere of disapproval.

3. That society is nothing more than an aggregate collection of individuals. Accordingly the wealth, the advantage, the profit of society as a whole is but the sum of the wealths, the advantages, the profits of the individuals composing it.

4. That every individual left to himself pursues his own interest his own way, and knows it better than anybody else. Accordingly, absence of restriction on the individual is the best means of serving the community. Social interest is identical with individual interest.

5. That every country has certain natural advantages. Left to themselves individuals will exert themselves in the directions to which these advantages point. It is, therefore, for the benefit of a country or nation that they should be left free to do so.

6. That in each country there is at any moment a certain given supply of capital and labour, which cannot be increased by any action of the State. Since, left to themselves, they will spontaneously flow into the employments most advantageous to themselves and consequently to the country, any action of a public authority which directs them towards employments to which they would not of themselves go, or keeps them in industries which they would otherwise leave, involves loss to the country.

7. That if another country can supply certain commodities more cheaply, it follows that that country must possess advantages which the importing country does not enjoy. Since these imports must be paid for by exports, they must be paid for by commodities in the production of which the importing country has an advantage. Each country thus obtains what it wants with the least expenditure of labour or capital, *i.e.* most cheaply, and benefits by international division of labour. Since the advantages in question are of divine appointment, to refuse to take the fullest advantage of international division of labour is to fly in the face of Providence. If the theistic conception is dropped, and the argument is based on utility, the offence is the equally serious one of disregarding common sense.

8. That the national capital and labour can be transferred from one occupation to another. If an existing industry cannot be profitably carried on owing to foreign competition, the capital and labour involved can be transferred to some other manufacture within the country, and must inevitably be so transferred in order to provide the additional commodities necessary to pay for the imports. That the foreign country will—indeed, must—take commodities in return for what it sends, proves that in some exportable commodities the home country has an advantage. The destruction of a native industry is in itself a proof that it has no economic right to exist.

9. That, left to themselves, people will buy whatever they want at the cheapest price. This, therefore, must be their interest. And since the State is a collection of consumers, and individual interest is social interest, the ultimate criterion of the interest of the State is the interest of consumers.

In these nine propositions and their corollaries consists the whole of the generally accepted economic doctrine of the century which followed upon the great work of Smith. That they were held to be sufficient and decisive as late as 1878 is very authoritatively stated in the most widely circulated of treatises on the subject—the lectures of Professor Fawcett, which appeared in that year and quickly passed through several editions. 'All the most effective arguments,' he remarks, 'that can now be urged in favour of free trade had . . . been stated with the most admirable clearness and force by Adam Smith, Ricardo, and other economists. In the pages of these writers are to be found many passages which furnish the best reply that can be made to the modern opponents of free trade.' [1]

1, 2. The first two of the propositions—that Nature is beneficent, and that Nature consists in the unrestricted freedom of every individual to pursue his personal desires and interest in his own way—were inextricably associated in the minds of the first generation of English economists. It will be sufficient for our purpose to consider them together, under the term Adam Smith himself employs in a famous passage. When all preference or restraint, he says, is completely taken away, it gives place to 'the simple system of Natural Liberty.' [2] The context shows that by 'system' Smith means both the doctrine and the condition of things which results when the doctrine is put into effect.

We need not spend much time over the genesis of this doctrine. If we knew nothing of Adam Smith but the 'Wealth of Nations,' and took care only to read certain parts of it, some sort of case might be made out for the view that the doctrine was for Adam Smith an induction from experience: this and this and this case of interference with natural liberty, we might suppose him to have found, were demonstrably harmful, and therefore, he concluded, all interference with natural liberty was harmful. No one need deny that some of the instances he cites did lend support to this contention; nor need anyone deny also that the contemporary system of governmental or corporate regulation was ill adapted to the needs of the capitalistic era then opening. But it would be to disregard all Adam Smith's antecedents as a philosopher; all that we know of the history and transformation of the conception of 'Nature' from the Greek thinkers downward; all the evident affiliation of Smith with his predecessor Hutcheson, and of both with Shaftesbury; and in particular it would be to ignore the essential unity of the 'Wealth of Nations' with Smith's other work, the 'Theory of Moral Sentiments,' to refuse to recognise that Smith took over the doctrine of Natural Liberty from current theology and moral philosophy. The movement of his mind was fundamentally deductive: natural liberty, he started with believing, is beneficent; he expected therefore to find all interferences with it harmful, and he had no difficulty in discovering instances.

[1] *Free Trade and Protection*, 6th ed. (1885), p. 3.
[2] *Wealth of Nations*, Bk. IV., ch. ix. (ed. Rogers, ii., 272).

Buckle has asserted that Adam Smith's greatness is shown by his basing everything in his Moral Philosophy upon Sympathy and everything in his Economics upon Self-interest, and by his leaving his readers to make the necessary adjustment between them. It would be a doubtful compliment, if true; but no one can suppose it to be true who has read his two works attentively. I am not concerned to maintain Smith's philosophical consistency; my own impression, for what it is worth, is that his system of moral philosophy is by no means water-tight. But Smith himself, down to the end of his life, thought of his Moral Philosophy and his Economics as forming one whole.[3] And the recurrence of certain characteristic phrases in the second of his books shows clearly enough that he looked back on his earlier work as laying his philosophical foundation.

It is so necessary that this should be realised if we are to judge fairly some of his successors, that I will ask you to let me adduce one or two pieces of evidence.

Perhaps the most formal statement of his belief will be found in the generalisations to which he is led when considering the social utility of 'resentment'—a passion which, he says, is 'commonly regarded' as 'odious.' Odious though it be, it is, he holds, useful; and it is useful, in spite of the fact that it is not itself the outcome of conscious reasoning. For, as the very existence of society is at stake, 'the Author of Nature has not entrusted it to man's reason to find out . . . the proper means of attaining this end.' He then proceeds to generalise—substituting a personified Nature for her Author. 'The economy of Nature is in this respect exactly of a piece with what it is upon *many other occasions*. With regard to *all* those ends which, upon account of their peculiar importance may be regarded, if such an expression is allowable, as the favourite ends of Nature, she has *constantly* not only endowed mankind with an appetite for the end which she proposes, but likewise with an appetite for the means by which alone the end can be brought about, for their own sakes and independently of their tendency to produce it. Thus self-preservation and the propagation of the species are the great ends which Nature seems to have proposed in the formation of all animals. But . . . it has not been entrusted to the slow and uncertain determinations of our reason to find out the proper means of bringing them about. Nature has directed us to the greater part of these by *original and immediate instincts*. Hunger, thirst, the passion which unites the two sexes, the *love of pleasure* and the *dread of pain* prompt us to apply these means for their own sakes, and without any consideration of their tendency to those beneficent ends which the great Director of Nature intended to produce by them.' You will notice how he again falls back into theistic phraseology.[4]

Scotch caution abundantly shows itself in both of Smith's books; and the method of hedging implied in the insertion of 'upon many occasions' is highly characteristic.[5] But such hedging is never intended to give,

[3] Compare the last paragraph of the first edition (1759) of the *Moral Sentiments* with the Advertisement to the sixth edition (1790).

[4] This is in the long note at the end of *Moral Sentiments,* Part II., Sec. I., ch. v. (Ward, Lock & Co.'s Reprint, p. 71, under the title *Essays* . . . by Adam Smith).

[5] Even this qualification, it will be noticed, disappears with respect to 'all the favourite ends of Nature,' where she has 'constantly' pursued the policy described.

and does not really give, any serious qualification to the general proposition. This is amusingly illustrated by two parallel passages employing an identical phrase. In the one he is commenting on the respect which mankind has for success, for wealth and greatness. This respect might certainly seem to the moralist extravagant; if not, what Smith himself calls it, 'the great and universal cause of the corruption of our moral sentiments.' He continues, however, unperturbed: 'This great disorder in our moral sentiments is by no means without its utility; and we may on this, as well as on *many other occasions*, admire the wisdom of God even in the weakness and folly of man. Our admiration of success is founded upon the same principle with our respect for wealth and greatness and is equally necessary for establishing the distinction of ranks and the order of society.' [6]

In the other passage, Smith is commenting on the fact that 'the world judges by the event and not by the design.' This, again, might well seem to the moralist unsatisfactory. And so, indeed, it is; but it is all for a good end. 'Nature, when she implanted the seeds of this irregularity in the human breast, seems, *as upon all other occasions*, to have intended the happiness and perfection of the species. . . . That necessary rule of justice that men in this life are liable to punishment for their actions only . . . is founded upon this salutary and useful irregularity concerning merit and demerit, which at first sight appears so absurd and unaccountable. But *every* part of Nature, when attentively surveyed, equally demonstrates the *providential care* of its Author, and we may admire the wisdom and goodness of God even in the weakness and folly of men.' [7]

The truth is that Smith was bound by his general philosophical position to generalise, however frequently Scotch caution might check him for the moment. For if 'the happiness of mankind' was 'the original purpose intended by the Author of Nature,' and if Nature was conceived as Smith conceived it, then he was prepared to find, on an 'examination of the works of Nature,' that they seemed all 'intended to promote happiness and to guard against misery.' [8] Any apparent defects must be the irreducible minimum of evil necessary for the existence of the good.

> 'All Discord, Harmony not understood;
> All partial Evil, universal Good,'

as Pope has it.

As early as the date of his 'Moral Sentiments' Smith began to find his philosophic optimism confirmed in the economic sphere. 'Success in every sort of business' is 'the reward most proper for encouraging industry, prudence, and circumspection. . . . Wealth, and external honours are their proper recompense, and the recompense which they seldom fail of acquiring.' And thus, 'the general rules by which prosperity and adversity are commonly distributed . . . appear to be perfectly suited to the situation of mankind in this life.' [9] The 'pleasures of wealth,' it is true, are vastly exaggerated by the imagination; but 'it is well that Nature imposes upon

[6] The matter is considered at length in two places: Part I., Sec. III., ch. iii. (Reprint, p. 56); and Part VI., Sec. III. (Reprint, p. 224).

[7] Part II., Sec. III., ch. iii. 'Of the Final Cause of this Irregularity of Sentiments.' (Reprint, p. 96.)

[8] Part III., ch. v. (Reprint, p. 146.)

[9] *Ibid.* p. 147.

us in this manner. It is this deception which rouses and keeps in continual motion the industry of mankind.' [10]

One more quotation will enable us, by the help of a phrase which reappears in the 'Wealth of Nations,' to pass from the ethical to the economic treatise. It is the passage in which he explains how beneficial to society in general and the poor in particular are 'the luxury and caprice' of the rich. 'They consume little more than the poor; and in spite of their natural selfishness and rapacity, though they mean only their own conveniency, though the sole end which they propose from the labours of all the thousands whom they employ be the gratification of their own vain and insatiable desires, they divide with the poor the produce of all their improvements. They are *led by an invisible hand* to make nearly the same distribution of the necessaries of life which would have been made had the earth been divided into equal portions among all its inhabitants; and thus, *without intending it*, without knowing it, advance the interest of the society and afford means to the multiplication of the species. When Providence divided the earth among a few lordly masters, it neither forgot nor abandoned those who seemed to have been left out in the partition.' [11]

You will have been anticipating the passage I now go on to in the 'Wealth of Nations.' It is that in which he explains how it is that 'every individual,' by directing the domestic industry of a country 'in such a manner as its produce may be of the greatest value,' though 'he intends only his own gain,' 'is in this, as in *many other cases, led by an invisible hand* to promote an end which was no part of his *intention*.' * You observe how the very terms of the former treatise reappear; not only the 'invisible hand,' but also 'intention' and 'end'; and you will realise that 'in many other cases' is not a qualification he intends to be taken seriously. The 'invisible hand' is not, as some have supposed, the chance survival of a picturesque literary phrase; the idea, in that or some equivalent phrase, is the *leit-motif* of all his writing.

However the doctrine grew up in Smith's mind that—as one of my predecessors in this Chair has expressed it—'the *natural* forces of human desires and aversions . . . will *naturally*, and without conscious intention on the part of the individual, lead to the greatest advantage of society,' and however much he may have supposed himself to have reached it by observation of surrounding facts, there can be no doubt, as that predecessor of mine has pointed out, that it 'became the starting point' of 'the school of propagandists' who gave Political Economy its English connotation.[12]

So much the starting point that it was unconsciously assumed. It hardly occurred to most writers explicitly to set it forth; and here, as elsewhere, we can be grateful to McCulloch for proclaiming what others were thinking. 'The principles on which the production and accumulation of wealth depend are inherent in our nature' . . . and again: 'The principles which form the basis of this science make a part of the original constitution of man and of the physical world.' [13] And Buckle, summing up with

[10] Part IV., ch. i. (Reprint, p. 162.)
[11] *Ibid.* (Reprint, p. 163.)
* *W. of N.*, Bk. IV., ch. ii. (II. 28.)
[12] Sir H. Llewellyn Smith, at the Meeting of 1910.
[13] *Principles* (1825), p. 15. (Reprint, p. 16.)

unbounded admiration more than thirty years later the teachings of Smith, declares 'there is a provision in the nature of things by which the selfishness of the individual accelerates the progress of the community.'[14] Where the beneficence of natural liberty is not positively asserted, it is of course implied in the use of so condemnatory a term as 'artificial' to designate any limitation of it: as for instance in the Merchants' Petition drafted by Tooke in 1820.

It can be easily understood that when Political Economy passed into the hands of a stockbroker like Ricardo and of utilitarian agnostics like the two Mills, the language of theism would fall into disuse. No longer were they inclined to echo the old saying 'Nature: that is God Himself.'[15] And it was not only because they had ceased to think theologically: it was because some at any rate could hardly fail to be more or less conscious that the turn Ricardo had given to the doctrine had deprived it of its optimistic character, and made it uncomfortably fatalistic. 'Nature' was still enthroned; and if 'God' means only a Supreme Power there was no reason why Nature should not continue to be called God, or God's Vicegerent—were it not that the Supreme Power which had established 'the Principle of Population' and 'the natural price of labour' could hardly be respected, let alone loved.

When, however, we get to the period of the Anti-Corn Law League there was a return to Smith's optimism and Smith's theism. 'The responsibility of having to find food for the people belongs,' says Cobden in 1846, 'to the law of Nature; as Burke says'—he continues—'it belongs to God alone to regulate the supply of the food of nations.'[16] It is congenial to him to appeal to 'the will of the Supreme Being'[17] and 'the moral government of the world';[18] and to describe Free Trade as 'the International Law of the Almighty.'[19] And with the return to a theistic conception went a return to the idea of natural rights, which the Benthamite economists had likewise thrown over. Thus the petition of the Manchester Chamber of Commerce, drawn up by Cobden and two of his friends in 1838, bases itself upon 'the unalienable right of every man freely to exchange the results of his labour for the productions of other people.'[20] The eloquent orator, W. J. Fox, refused on this ground to compromise on Free Trade: 'It is "the very stuff o' the conscience": it is a principle upon which we have made up our minds, as embracing the right of man anterior to the existence of civilised society.'[21] And after the further lapse of a quarter of a century, the editor of Bright's and Cobden's 'Speeches,' Thorold Rogers, becoming Professor at Oxford and writing 'A Manual for Schools and Colleges,' 'assumes,' as of course, 'that there are such rights as are called "natural," and that these are the inalienable conditions under which individuals take part in social life.'[22]

[14] *Civilisation in England*, vol. ii., ch. vi.

[15] The mediæval legist Azo 'explains Ulpian's *natura* by *id est ipse Deus*.' Pollock, *Essays*, p. 42, from Maitland.

[16] Speech of Feb. 27, 1846.

[17] Speech of Aug. 25, 1841, quoting a petition of ministers of religion.

[18] Speech of Oct. 19, 1843.

[19] According to Mallet, Intro. to *Political Writings of Cobden*, p. vi.

[20] Text in Hirst's collection, *Free Trade and the Manchester School* (1903), p. 142.

[21] Speaking in 1844, *Ibid.* p. 174.

[22] *Manual*, 2nd ed. revised, 1869, p. 223.

How far the return to Adam Smith's type of optimistic theism was due to the real religious sentiment of men like Cobden, to their own reading of the great Scotch master, and to the contemporary English environment, and how much it may have been due to the influence of the contemporary French writer Bastiat, it is not easy to say. Sir Louis Mallet, one of the literary custodians of Cobden's fame and associated with him in negotiating the French Treaty of 1860, regards it as 'one of those coincidences which sometimes exercise so powerful an influence on human affairs' that, while Cobden was leading a political movement in England, 'Frederic Bastiat was conceiving and maturing in France the system of political philosophy which still remains the best and most complete exposition of the views of which Cobden was the great representative.' 'These two men,' he affirms, 'were necessary to each other. Without Cobden, Bastiat would have lost the powerful stimulant of practical example. . . . Without Bastiat, Cobden's policy would not have been elaborated into a system.' [23]

Bastiat has had hard measure dealt to him by later writers. In exchange for the extravagant laudation he received at the time from politicians and popular writers, he has been treated by recent academic economists with a certain patronising contempt. It is allowed that his apologues or parables, like the Petition of the Candle Makers against the Sun, are amusing *reductiones ad absurdum* of some of the demands of the Protectionist man-in-the-street. But he is dismissed as 'a lucid writer, but not a profound thinker'; and the doctrine ascribed to him—'that the natural organisation of society under the influence of competition is the best not only that can be practically effected but even that can be theoretically conceived'—is characterised as 'extravagant.' [24]

I must avow that I have found nothing in Bastiat's most optimistic and theistic passages which is more than a more emotional repetition of Smith in the 'Moral Sentiments.' Smith tells us of 'that divine Being whose benevolence and wisdom have from all eternity contrived and conducted the immense machine of the universe, so as at all times to produce the greatest possible quantity of happiness.' [25] Bastiat uses the same mechanical image: 'The leading idea of this work, the harmony of interests, is religious. For it assures us that it is not only the celestial but also the social mechanism which reveals the wisdom of God and declares His glory.' [26] And the Divine Hand reappears: 'Since in the sphere of labour and exchange the principle "each for himself" must inevitably prevail as motive power, it is marvellous how the Author of things has made use of it to realise in society the fraternal motto "each for all." His skilful Hand [27] has made an instrument out of an obstacle. The general interest has been entrusted to private interest; and the former is inevitable precisely because the latter is indestructible.' [28] Before we of this generation are contemptuous of Bastiat, it is only just

[23] *Cobden's Political Writings* (1878), Intro., p. vi.

[24] Marshall, *Principles*, 4th ed., p. 64.

[25] *Moral Sentiments*, Pt. VI., Sec. II., ch. iii. (Reprint, p. 210.)

[26] Preface *To the Youth of France* to his *Harmonies Économiques* (1850). In English translation: *Harmonies of Political Economy* (1860), p. 9.

[27] 'Son habile main.'

[28] *Œuvres Choisies*, ed. Foville, p. 269.

to look into the rock whence he was hewn, and to the hole of the pit whence he was digged.

The truth is, Bastiat went behind Malthus and Ricardo, back to Adam Smith. He pointed out that what distinguished 'the Economist school' of his time from various Socialist schools was at bottom this: that the former believed and the latter did not in the necessary harmony of unrestricted individual interests. This harmony was the principle from which 'the Economist school' started in their arguments in favour of economic freedom. Their practical conclusions were in themselves correct; but the premise, the starting point, could not be correct, Bastiat averred—the harmony did not in reality exist—if the Malthusian doctrine of Population was true and the consequent Ricardian doctrine of Rent. And so, to save the premise, these doctrines must be thrown over.[29] And that, of course, is just what Cobden did, when he argued so frequently and strenuously against the fundamental proposition of Ricardo that the price of food regulates the rate of wages.[30]

Is it necessary to say that nowadays no serious thinker believes in the two propositions with which I have commenced? 'Natural' and 'artificial' are words we still use to beg a question; but no one is any longer at all thoroughgoing in their application. 'Nature,' as distinguished, as Adam Smith does, from 'the slow and uncertain determinations of our reason,' no longer has the comforting sound it once had. We may not think of Nature as 'Red in tooth and claw,' or say, with another great poet, 'Nature and man can never be fast friends'; but we can save Nature's character only by including in it precisely what Smith omitted: human reason. And when we put aside abstract prepossessions and simply watch the operation of social forces, we discover that on neither side of the antitheses, Freedom and Control, Liberty and Order, Competition and Combination, is there a necessary preponderance of good or evil. Factory Laws, Education Laws, Sanitation Laws alike show that no modern civilised State any longer believes that social interests can be left to the

[29] It is so easy to miss the precise point in a translation that it will be well to quote the original. 'J'ai dit que l'Ecole économiste, *partant de* la naturelle harmonie des intérêts, *concluait* à la Liberté. Cependant, je dois en convenir, si les économistes, en général, *concluent* à la Liberté, il n'est malheureusement pas aussi vrai que leurs principes établissent solidement *le point de départ*: l'harmonie des intérêts.' And again: 'La *conclusion* des économistes est la liberté. Mais, pour que cette conclusion obtienne l'assentiment des intelligences et attire à elle les cœurs, il faut qu'elle soit solidement fondée sur cette *prémisse*: les intérêts, abandonnés à eux-mêmes, tendent à des combinaisons harmoniques, à la prépondérance progressive du bien général. Or, plusieurs d'entre eux, parmi ceux qui font autorité, ont émis des propositions qui, de conséquence en conséquence, conduisent logiquement au mal absolu, à l'injustice nécessaire, à l'inégalité fatale et progressive, au paupérisme inévitable.'

[30] It is interesting to pass from the first three paragraphs of Ricardo's ch. v. on Wages (1817) to Cobden's speeches of Feb. 24, 1842, and Feb. 8, 1844. Cobden avowedly bases himself in the matter of wages on Adam Smith; Speech of July 3, 1844. (*Speeches*, 1880, p. 105; cf. p. 119.) Compare the attitude toward Malthus and Ricardo of Cobden's friend, Thorold Rogers, who, in his *Manual*, speaks of Bastiat as 'the great French economist.' But before Bastiat there was at least one notable Free-trader who thought it necessary to protest against the Malthusian doctrine of Population and the Ricardian doctrine of Rent in order to preserve his exuberantly optimistic outlook. This was G. Poulett Scrope, the geologist and M.P., in his *Principles of Political Economy*, 1833. See Preface, p. viii, to edition of 1873.

unhampered working of immediate individual desires and impulses. It is arguable that 'Liberty' may still be the best policy to pursue in the matter of foreign trade. But the contention no longer starts with the immense presumption in its favour which it enjoyed so long as it was deemed the master key to a divine government of the world.

3, 4. The individualistic or 'atomistic' conception of society, or of the State as its organised expression, and the doctrine of the identity of individual and social interests (in the sense that the pursuit of individual interests must necessarily, in general, conduce to social interests) were, perhaps, not inevitably associated ideas. For society might be conceived of as a mere aggregation of individuals; and yet, within the society so formed, the pursuit of individual interests—since all individuals are not equally powerful—might conceivably be regarded as injurious to the majority, and, in that sense, to society itself. Some such view was inculcated by Hobbes. From such a conclusion Smith and his followers were saved by their underlying confidence in Nature. For if each individual retained or should retain in society his natural rights, and if the final outcome was bound to be good, that could only be because the pursuit of individual rights resulted in the common advantage. It would be superfluous to point out that the individualist view of the essential nature of society, and of the State as its organised expression, led to the limitation of State functions and to the policy commonly known as *laissez-faire*.

As in the case of Natural Liberty we need not ask how the atomistic conception of the social union came to Adam Smith. That it characterises his school is very certain. But Smith was a man of wide reading, and knew too much to readily give himself away by generalities. It is interesting to see how his followers forced his ultimate principles into the open. A good example is furnished by McCulloch. Time has dealt hardly with McCulloch. His name has almost disappeared from modern treatises. But he was the man from whom the general British public mainly learnt its Political Economy between 1825 and 1850; and the republication of his first edition in cheap reprints secured currency for his teaching long after the middle of the century in certain circles, and that in its earliest and least qualified form. Peacock with his 'MacQuedy' in 1831, and Carlyle with his 'McCroudy' in 1850, knew well enough what they were about;[31] for McCulloch might reasonably be taken as 'the typical economist of the day.'[32]

McCulloch has been employed in setting forth the general argument for individual enterprise. As is his wont, he does not scruple to appropriate, without marks of quotation, choice sentences of Adam Smith—as, less frequently, of Ricardo.

Smith had written thus: 'Every individual is continually exerting himself to find out the most advantageous employment for whatever capital he can command. It is his own advantage, indeed, and not that of the society which he has in view. But the study of his own advantage naturally, or rather, necessarily, leads him to prefer that employment which is most advantageous to the society.'[33]

[31] In Peacock's *Crotchet Castle* and Carlyle's *Latter-Day Pamphlets.*

[32] Leslie Stephen, *The English Utilitarians*, ii., p. 226.

[33] *W. of N.*, Bk. IV., ch. ii. (Rogers' ed., ii. 26.)

Now listen how McCulloch copies this verbatim, but adds 'labour' to 'capital,' and emphasises the completeness of the social benefit. Notice still more how he, quite correctly, inserts into the middle of the argument the fundamental principle on which it rests: 'It may be observed that every individual is constantly exerting himself to find out the most advantageous methods of employing his capital and labour. It is true that it is his own advantage and not that of the society which he has in view; but, as a society is nothing more than an *aggregate collection of individuals*,[34] it is plain that each in steadily pursuing his own aggrandisement is following that precise line of conduct which is most for the public advantage.'[35]

The large assumption on which the conclusion depended, viz. that individuals know their own interest better than any other man, or 'select number of men,' can teach them is, with McCulloch, 'an admitted principle in the Science of Morals as well as of Political Economy'* which hardly calls for exposition.

An individualist view of the social bond involved, as I have already observed, a severe limitation of the functions of the State, or, in Adam Smith's language, of the 'sovereign.' Herein again Bastiat brings out what is implicit in Adam Smith. In his article on the State, written in 1848, in the midst of the Socialistic agitation of the period, he prides himself on being able thus to characterise it: 'The State is the great fiction by means of which everyone tries to live at the expense of everyone[36]. . .

'To-day as aforetime, everyone would like to profit by the toil of others. One doesn't dare to profess such a sentiment; one conceals it from oneself. So what does one do? We invent an intermediary; we turn to the *State*; and one class after another comes and says to it: "You, who can properly and honestly do so, take from the public; and we will share." Alas! the State has only too great an inclination to follow this diabolical counsel; for it is composed of ministers and officials—men, in fact, who, like all other men, desire at heart, and seize every opportunity, to increase their own riches and influence.'

For quite such sweeping language from an English pen we have to come to America. And here is a characteristic passage from that forcible little book by the late Professor Sumner of Yale, 'What Social Classes owe to Each Other':[37] 'As an abstraction, the State is to me only All-of-us. In practice—that is, when it exercises will or adopts a line of action—it is only a little group of men chosen in a very haphazard way by the majority of us . . . "The State," instead of offering resources of wisdom, right reason, and pure moral sense beyond what the average of us possess, generally offers much less of all these things'; and so on.

In the last half-century we have seen a high doctrine of the State entering into England, and in a lesser measure into America, as part of the influence of the Hegelian philosophy and of a renewed appreciation of the

[34] McCulloch's own italics.

[35] *Principles of Political Economy* (1825), Pt. V., ch. iv. (Reprint, p. 74.)

* Reprint, p. 16.

[36] 'L'Etat, *c'est la grande fiction à travers laquelle* TOUT LE MONDE *s'efforce de vivre aux dépens de* TOUT LE MONDE' (Bastiat's own capitals and italics).—*Œuvres Choisies*, ed. Foville, p. 94. There is a poor translation in a volume edited by D. A. Wells, *Bastiat, Essays in Political Economy* (1893).

[37] 1885, p. 9.

Greek view of the State. We have seen the High-State doctrine confirmed by the visible efficacy of much positive State action. We have seen it, more recently, somewhat discredited by its association in Germany with a deification of the State which has seemed immoral; and although the State in all countries undertook during the Great War, with quite unexpected success, novel functions, its activity has, for the time, undoubtedly left behind a certain soreness in some of the business interests affected. Moreover, there has been much analysis in recent years of the conceptions *Society* and *State*; much consideration of the place of groups or associations within the State, and of a conceivable partition of functions. There are schools of political thought who are so indignant with the use which Governments calling themselves 'the State' have made of their powers that they propose to abolish the State altogether: although their measures, when they seize power, indicate clearly enough that what they believe in is something similar under another name. For all these reasons, I naturally do not intend to set forth any view of my own, either as to Society or the State. I am content to have reminded you of the view entertained by the economists of the century we are considering. I do not suppose it would satisfy any serious thinker now. He might think Free Trade expedient; but he would not base it upon so one-sided and unhistorical a conception of the social union.

5. The idea that countries differ from one another in their physical productive resources, and that this is the occasion and justification of foreign trade, had been a commonplace with writers centuries before Adam Smith. It is to be found well developed in the letters of Seneca; it reappears in the great encyclopædic treatise of Aquinas; [38] and it was transmitted to the modern world by Grotius. [39] But there can hardly be any doubt that it came to Adam Smith from the well-known essays 'Of the Balance of Trade' and 'Of the Jealousy of Trade,' published by his friend David Hume in 1752 and 1758. Hume had written: 'Nature, by giving a diversity of geniuses, climates and soils to different nations, has secured their mutual intercourse and commerce so long as they all remain industrious and civilised.' And he had furnished Smith and his successors with a convenient shorter expression by remarking: 'When any commodity is denominated the staple of a kingdom, it is supposed' (*i.e.* understood) 'that this kingdom has some peculiar and *natural advantages* [40] for raising the commodity.'

Hume also led the way for Smith to draw the conclusion that interference with the international trade which would arise from the divergency in national advantages would be unwise. And it is an illustration of the

[38] This learning is not my own. References will be found in Kautz, *Geschichtliche Entwickelung der Nat. Oek.*, pp. 156, 215.

[39] Grotius (*De Jure Belli ac Pacis*, II., 2, 13, 5) quotes from the Greek rhetorician Libanius, of the fourth century after Christ, a passage which he translates thus: 'Deus non omnia omnibus terrae partibus concessit, sed per regiones dona sua distribuit, quo homines alii aliorum indigentes ope societatem colerent. Itaque mercaturam excitavit.'

[40] The expression had been used, in 1691, by John Locke, in his *Considerations of the Lowering of Interest* (Reprint in *Essays*: Ward, Lock & Co., p. 566). He says, of Commerce: 'For this the advantages of our situation, as well as the industry and application of our people . . . do naturally fit us. By this, . . . trade left almost to itself, and assisted only by the *natural advantages* above mentioned, brought us in plenty of riches.' But Locke was far from drawing the Free Trade conclusion.

hold which the current Nature philosophy had on men's minds that Hume, whose own theism was of the most tenuous and hesitating character, puts the conclusion in theistic language : 'These numberless bars, obstructions and imposts which all nations of Europe . . . have put upon trade . . . deprive neighbouring nations of that free communication and exchange which the Author of the world has intended by giving them soils, climates and geniuses so different from each other.'

It need hardly be said that this religious interpretation long continued to be usual. As the great financier Alexander Baring, later known as Lord Ashburton, declared, in presenting the Merchants' Petition to the House of Commons in 1820 : 'It is one of the wise dispensations of Providence to give to different parts of the world different climates and different advantages, probably with the great moral purpose of bringing human beings together for the mutual relief of their wants.' [41]

'Natural advantages,' it will be allowed, will commonly be taken to mean advantages based on geographical conditions. This is what the reader, left to himself, would understand by Ricardo's language, when he says that 'a system of perfectly free commerce' uses most efficaciously 'the peculiar powers bestowed by nature' ; [42] or by Cobden's language, thirty years later, when he speaks of England as setting 'the example of giving the whole world every advantage of clime and latitude and situation.' [43]

Smith is avowedly taking a strong case when he remarks that 'by means of glasses, hot-beds and hot walls very good grapes can be raised in Scotland, and very good wine too can be made of them—at about thirty times the expense at which they can be imported.' [44] But, if this is an extreme case, it is something equally clear in essential character, though usually less in degree, that the phrase 'natural advantages' is calculated to imply. And this is how Ricardo himself interprets it : 'It is this principle which determines that wine shall be made in France and Portugal, that corn shall be grown in America and Poland, and that hardware and other goods shall be manufactured in England.' [45]

It will be remembered that Ricardo was writing in 1817 : it was then thought that English hardware rested upon natural blessings in the way of coal and iron which other nations did not possess. The 'natural advantages' which the United States and Germany, to mention no other countries, were destined to find in their coal and iron deposits had not yet been discovered. As late as 1832 McCulloch could write in his 'Dictionary of Commerce': 'The hardware manufacture is one of the most important

[41] Hansard (N.S.) I., p. 165, quoted in Page, *Commerce and Industry* (1919), I., 55.

[42] Chap. vii., on *Foreign Trade.*

[43] Speech of Feb. 27, 1846. A contemporary variant is 'varieties of climate, situation and soil,' in the *Edinburgh Review* for Jan. 1841 (a reference I owe to the late Professor Sidgwick). In Thorold Rogers we find a fresh spring of fervour derived from Cobden and Bastiat. The chapter on Foreign Trade in his *Manual* (1868) thus begins : 'The various regions of the earth are variously favourable to the growth of vegetable and animal products. Different countries too have different geological characteristics.' The exposition of 'special advantages' by the economist who replaced Rogers in the Oxford chair is on the same lines : Bonamy Price, *Practical Political Economy* (1878), p. 309.

[44] II., p. 31.

[45] *Principles*, p. 157.

carried on in Great Britain; and from the abundance of iron, tin and copper ores in this country, and our inexhaustible coal mines, it is one which seems to be established on a very secure foundation.' [46]

'Natural advantages,' however, as a basis for the universal application of the policy of free trade, was likely to suggest two comments. One is that the greater cheapness with which one country can produce goods as compared with another is obviously in some cases due to no peculiar advantage in the geographical sense, but simply to the historical fact that the manufacture was established there earlier. The other is that a country may even possess geographical advantages for a particular production but be unable to develop them if importation is free, because, for the time being, another country is producing more cheaply. If the 'intention' of 'the Author of the world,' or of 'Nature,' is shown by the provision of particular physical resources, it can hardly be supposed proper to allow it to be indefinitely 'counteracted'; [47] and this vital point in the argument was seized upon by Alexander Hamilton. Hamilton, the author of the greater part of 'The Federalist,' is the most considerable name in the political science of the United States. His famous 'Report on Manufactures,' written in 1790, only fourteen years after the appearance of the 'Wealth of Nations,' and long before List and John Stuart Mill, shows a powerful mind working on the material presented to him by Adam Smith and the French economists, but with the needs and conditions of a new country before his eyes. And as soon as we realise that 'advantages' was a key-word in the discussion, we cannot but appreciate the dexterity with which Hamilton employs it to justify protection. Writing at a time when water was still the usual motive-power for the new machinery, he alleges that in that respect 'some superiority of advantages may be claimed' for the United States; as to the cost of materials, 'the advantage upon the whole is at present upon the side of the United States'; and, generally, 'it is certain that various objects in this country hold out advantages which are with difficulty to be equalled elsewhere.' [48]

Adam Smith was quite shrewd enough to foresee criticism on this line. He meets it boldly: 'Whether the advantages which one country has over another be natural or acquired is in this respect' (*i.e.* cheapness) 'of no consequence. So long as the one country has these advantages and the other wants them, it will always be more advantageous to the latter rather to buy of the former than to make.' [49] This is of course perfectly true, but inconclusive. That one policy is clearly more advantageous in the short run does not prove that it must be more advantageous in the long run.

[46] J. L. Mallet in his *Diaries* (excerpted in *Political Economy Club, Centenary Volume*, 1921) comments on the success of this Dictionary: 'Two thousand copies of the first edition sold, at 2*l.* 10*s.* a copy, in the course of nine months.' Cobden, in 1835, described it as 'a work of unrivalled usefulness, which ought to have a place in the library of every merchant and reader who feels interested in the commerce of the world.'

[47] In the case of the exchange of English cloth for Portuguese wine, 'the intention of Nature' was indicated to McCulloch by, *inter alia*, 'the superiority of the wool of England, our command of coals,' etc. (Reprint, p. 71.)

[48] In the reprint in Taussig's collection: *State Papers and Speeches on the Tariff* (Cambridge, Mass., 1893), pp. 35, 36, 39, and elsewhere.

[49] Bk. IV., ch. ii. (II., p. 31.)

The form of the long-run idea with which we are most familiar in England is the concession which Mill makes, as he says,' on mere principles of political economy,' with respect to the possible wisdom of imposing protective duties ' in hopes of naturalising a foreign industry in itself perfectly suitable to the circumstances of the country,' *i.e.*, as he goes on to say, ' where there is no inherent disadvantage.' [50] This, the so-called ' Infant Industries ' argument, I need not further elaborate. Mill recognises that such a policy involves a burden so long as the new industry cannot stand without protection ; but ' a protecting duty will sometimes be the least inconvenient mode in which the nation can tax itself for the support of such an experiment.' It may be remarked that Mill's statement of the economic and psychological difficulties under which a new industry, in itself perfectly suited to a country, will ordinarily labour, is nothing more than what Hamilton had said fifty-eight years before. [51] Neither of them mentions a consideration which modern business has made of vast importance : the greater economy of manufacture which large-scale production enjoys owing to the wider distribution of overhead charges.

The form in which the same idea was presented to the German public by List was of more philosophical generality. It is summed up in the contrast between a policy based on present ' exchange values '—which is his not unjust way of paraphrasing the language of Adam Smith—and a policy based on ' productive powers.' By suffering a present loss, a country may secure for itself a permanent source of wealth, which may repay, many times over, the initial loss.

I do not propose to enter into the tangled and highly controversial question of the extent to which the policy of protecting infant industries or developing productive powers has been or can be wisely applied in particular countries, at different stages of development, and with varying physical resources. I do not forget what is said, and said with a good deal of obvious justice, about the selfishness of particular interests, and about infants not growing up. It is not necessary to substitute for the belief in the necessary beneficence of human selfishness under free trade any belief in the necessary beneficence of human selfishness under protection. But it is fair, I think, to say that experience, since the time of List and Mill, is not altogether barren of what may reasonably be regarded as successful applications of the List and Mill principle. As my purpose is merely to examine the free trade doctrine of Adam Smith and of the century following as a piece of abstract argument, I will take only one case.

The tariff history of the United States has long been the happy hunting-ground for those who sought evidence of the sordidness of protectionist politics. The conjunction of the development of vast physical resources with the working, for the first time on a big scale, of practical democracy, created conditions not always favourable to political virtue. ' Lobbying ' has become a term of such evil sound that to some minds it makes further argument unnecessary.

If, in this sea of dubious issues, any writer can be supposed to steer a judicious course, I suppose it is Professor Taussig, the colleague by whose side I was proud to serve many years ago at Harvard. In successive

[50] Bk. V., ch. x., p. 1.

[51] See the ' very cogent reasons ' set forth by Hamilton, p. 29, *seq.*

editions of his book since 1882, he has earned our gratitude by putting before us, if not all, at any rate most of, the main facts of United States tariff history. Moreover, he has been one of the few writers who have illustrated from modern experience the Ricardian doctrine of comparative costs, the more subtle form of the general doctrine of natural advantages. And now let us listen to what he has had recently to say of the iron industry of the United States during the forty years preceding 1915.[52] I am anxious not to involve him an inch beyond the distance he would be willing to travel. I will therefore quote a sufficiently long passage, and will add that, to do him complete justice, it should be read *in situ.*

'It might be alleged that the iron industry would have advanced during the forty years in much the same way, protection or no protection. And yet the unbiassed enquirer must hesitate before committing himself to such an unqualified statement. Rich natural resources, business skill, improvements in transportation, widespread training in applied science, abundant and manageable labour supply—these, perhaps, suffice to account for the phenomena. But would these forces have turned *in this direction* so strongly and unerringly but for the shelter from foreign competition? Beyond question, the protective system caused high profits to be reaped and the stimulus from great gains promoted the unhesitating investment of capital on a large scale. . . . Thereafter, the community began to get its dividend. Prices fell. . . . The same sort of growth would doubtless have taken place eventually, tariff or no tariff; but not so soon, or on so great a scale.

'No one can say, with certainty, what would have been; and the bias of the individual observer will have an effect on his estimate of probabilities. The free trader . . . will be slow to admit that there are any kernels of truth under all this chaff. . . . On the other hand, the firm protectionist will find, in the history of the iron trade, conclusive proof of brilliant success. And very possibly those economists who, *being in principle neither protectionists nor free traders*, seek to be guided only by the outcome in the ascertained facts of concrete industry, would render a verdict here not unfavourable to the policy of fostering "national industry."'

The fact that such a verdict is possible in an outstanding case of this magnitude is not likely to impede the remarkable inversion of the old 'natural advantages' argument which we can see taking place nowadays in several directions. There has, of late, been an increase in the number of States which have independent control over their fiscal policy. The belief—which may or may not be well founded—that these countries are fortunate in their climates, or soils, or mineral resources, or water-power, or any other of the physical gifts of their geographical situation—and these are what the ordinary man means by 'advantages'—is now suggesting to them that, as with any other estate, it may pay them to expend something on development. Tariffs or bounties are, of course, from this point of view, simply forms of development expenditure. They would be inclined to echo the words of Adam Smith, though with a different application: 'What is prudence in the conduct of every private family, can scarce be folly in that of a great kingdom.'[53]

[52] *Some Aspects of the Tariff Question* (1915), p. 150.
[53] Bk. IV., ch. ii. (II., p. 29.)

An obvious case in point is India, in its new constitutional character. In 1922 the Indian Fiscal Commission, after pronouncing for a policy of protection 'with discrimination,' recommended the appointment of a Tariff Board to exercise that discrimination, and laid down the principles by which it was to be guided. And the very first is: 'The industry must be one possessing natural advantages, such as an abundant supply of raw material, cheap power, a sufficient supply of labour, or a large home market.'

In this present year the Indian Tariff Board has made its first report on a specific industry. It recommends protection for the Indian steel industry on these grounds: 'India possesses great natural advantages for the manufacture of steel, owing to the richness and abundance of the iron-ore deposits and the comparatively short distance which separates them from the coal-fields. The natural advantages are so great that eventually steel manufacture in India should be possible at as low a cost as in any other country.' Perhaps I had better say that I have no opinion on the particular proposal myself. I do not know whether the rich and abundant iron-ore deposits do in fact exist. But if they do, they are what the ordinary man means by 'natural advantages.'

To the Smithian economist, need I say the only proof that a country has an 'advantage' is the fact that it can produce more cheaply? 'Advantage' with him is a comparative not a positive idea. And yet it carries with it an implication that does not necessarily belong to it. In this respect it is like the biological conception of the 'fittest' to survive, or, to come nearer home, the economist's employment of 'utility.' 'Advantage' suggests that its possession is necessarily a good thing for the country which has it. But, in the comparative sense, every country which has a foreign trade at all must have an 'advantage' of some kind or other, or it would not be able to export. Anything which enables it to produce exports more cheaply than it is worth while for the importing country to produce them is an 'advantage.' Read Professor Taussig's books: you again and again come on the idea that the reason why the United States should not enter upon this or the other branch of production is that the commodities in question—*e.g.* beet sugar—are more cheaply produced abroad by docile, unintelligent labour: 'an inferior class which is utilised, perhaps exploited, by a superior.' He comes as near contempt for them as is possible for a humane man. But if, in the interchange of American machinery for European sugar, America's advantage is in its high-grade labour, by parity of reasoning the economic advantage of Europe is in its low-grade labour. And while this may be a reason for satisfaction on America's part, it is not so evidently a reason for satisfaction on Europe's part.

And, indeed, as soon as we begin to take a large view of history, it is quite certain that the utilisation of comparative advantages has sometimes been either a curse or a very mixed blessing. We are all familiar with Polish corn as supplying something like a local habitation and a name to the argument as to comparative costs. [54] But there is reason to believe that the export of corn from the Baltic lands to the countries of Western Europe was one of the causes for the depressed position of the peasant of

[54] See *e.g.* James Mill, *Elements* (1821), pp. 84-88, 135-137; followed by J. S. Mill, *Principles*, Bk. III., ch. xvii., § 2.

the Baltic lands in the 17th and 18th centuries.[55] And in the 19th century, when the Prussian *Junker* was a strong free trader in order to get a foreign market for his corn, he consolidated the economic 'advantages' of the lands east of the Elbe by buying up peasants' holdings and creating an agricultural labourer class which has become the most unsatisfactory feature in the German agricultural position.[56] Similarly, I suppose we all feel that the expansion of the American cotton area, and with it of slavery—during a period when the Southern planters were ardent free traders and anxious that England should be free to buy their raw cotton with its manufactures[57]—was a means of elevating the coloured race which it is difficult to look back upon with equanimity.

6. The next idea with which we have to deal is that every country has a particular supply of capital and labour, and that the State can do nothing, by protective measures, beyond diverting them to what is presumably a less profitable employment. This is stated by Adam Smith, first generally: when he says that a monopoly of the home market frequently turns towards a particular employment 'a greater share of both labour and stock of the society than would otherwise have gone to it'; and then when he makes everything depend on capital, and says that 'no regulation of commerce can increase the quantity of industry beyond what its capital can maintain: it can only divert a part of it.'[58] 'Diversion' is the key-word.[59]

I will follow Smith's example by concentrating first on capital. And as soon as one looks into the exposition as found in Smith or McCulloch or John Stuart Mill, it must be apparent that the idea has a close resemblance to another once dominant[60] which Mill himself publicly abandoned in 1869, and which few English-writing economists have since had the temerity to say a good word for: the so-called Wage-fund Doctrine. In formulating the 'diversion' argument Smith uses language about wages of which the doctrine of the Wage Fund, as defined later, was merely a crystallisation: 'As the number of workmen that can be kept in employment by any particular person must bear a certain proportion to his capital, so the number of those that can be continually employed by all the members of a great

[55] See the interesting account in Naudé, *Getreidehandelspolitik*, I., 385 (in the series *Acta Borussica*: *Denkmäler der Preussischen Staatsverwaltung*, 1896). Naudé attributes the social condition of Poland, the cause of most of its political troubles, to the fact that its Government was not allowed by the landlords in the eighteenth century to pursue a mercantilist policy.

[56] See *Memorandum V.* on *Germany*, by the present writer, in *Final Report* of the Agricultural Tribunal of Investigation (1924), especially §§ 3, 4, 10.

[57] The English reader to whom the connection between slavery and the free trade views of the Southern States may be unfamiliar will find some of the relevant facts in Dewey, *Financial History of the United States* (1903), § 80; Bogart, *Economic History of the United States* (1907), § 217; Coman, *Industrial History of the United States* (1905), p. 190.

[58] II., pp. 25-26; cf. p. 272. Cf. J. S. Mill, *Principles*, I., v., § 1; Rogers, *Manual*, p. 235.

[59] The phraseology was probably suggested by Hume, who, expounding an idea considered below, says, 'If the spirit of industry be preserved, it may easily be diverted' (Essay *Of the Jealousy of Trade*).

[60] How dominant we are inclined to forget. But we may be reminded of it by reference to the once famous work of Buckle, *History of Civilisation* (1857), Vol. II., ch. vi., p. 357. Buckle speaks of it as 'this vast step in our knowledge.'

society must bear a certain proportion to the whole capital of that society, and never can exceed that proportion.' [61]

What Mill said about the Wage Fund is equally applicable to 'the capital of a society' in its relation to industry: it is 'not regarded as unalterable, for it is augmented by saving and increases with the progress of wealth; but it is reasoned upon as at any given moment a predetermined amount.' [62] By a writer like McCulloch, who delights to make things superabundantly clear, this is expressly stated: 'No country can possibly employ a greater number of workmen than its capital can feed and maintain. But it is plain that no restrictive regulation can of itself add one single atom to the capital.' [63]

The reason, of course, is that given by Adam Smith: 'The industry of the society can augment only in proportion as its capital augments, and its capital can augment only in proportion to what can be gradually saved out of its revenue.' [64]

But all this rests upon a view as to the character and extent of the fluidity of capital which was current among the writers of the period we are considering but which subsequent experience has shown to require profound modification. It was a view which, as we now see, combined an exaggerated estimate of the extent to which already invested capital is transferable within a country with a quite insufficient estimate of the extent to which newly accumulated capital is transferable as between one country and another.

As to the export of capital, Ricardo struck the note in 1817: 'Experience shows that the fancied or real insecurity of capital, when not under the immediate control of its owner, together with the natural disinclination which every man has to quit the country of his birth and connections, and intrust himself, with all his habits fixed, to a strange Government and new laws, check the migration of capital. These feelings, which I should be sorry to see weakened, induce most men of property to be satisfied with a low rate of profits in their own country, rather than seek a more advantageous employment for their wealth in foreign nations.' [65]

All these human touches—'fixed habits,' and so on—are more appropriate to the age before joint-stock companies than to ours. Ricardo's account of the situation is so moderately expressed that it may be defended, even for our time, by a charitable interpretation. But the conclusion drawn by the succeeding generation was in fact a pretty sweeping one. To this clear testimony is borne by that Ricardian of Ricardians, Professor Cairnes, writing in 1874: 'The assumption commonly made in treatises of Political Economy is that, as between occupations and localities within the same country, the freedom of movement for capital and labour is perfect, while, as between nations, capital and labour move with difficulty or not at all.' [66]

[61] II., p. 26.
[62] *Dissertations and Discussions*, IV., p. 42, *seq.*, excerpted in my edition of Mill, p. 992.
[63] Reprint, p. 73.
[64] Bk. IV., ch. ii. (I. 30.)
[65] *Principles*, ch. vi., p. 161.
[66] *Some Leading Principles of Political Economy Newly Expounded* (1874), p. 302.

Alexander Hamilton as early as 1790 showed a more statesmanlike prevision of the future trend of affairs: 'Notwithstanding there are weighty inducements to prefer the employment of capital at home, even at less profit . . . yet these inducements are overruled either by a deficiency of employment or by a very material difference in profit. . . . The aid of foreign capital may safely and with considerable latitude be taken into calculation' [67] by a country in the then position of the United States.

The history of Foreign Investment and its relation to Production is so far an almost untrodden field for the economic enquirer. Some sort of impression of the magnitude of the forces set at work may be given by the calculation that, before the war, British investments in other lands amounted to some 3,500 millions of pounds sterling, almost one-fourth of the total wealth of the United Kingdom,[68] or by the 'common belief in the City (of London) prior to the war that the annual savings of the United Kingdom were than about 400*l*. millions, and were devoted half to foreign and half to home investment.' [69]

No one, I hope, will jump to the conclusion that what I am maintaining or even desirous of suggesting is that investment in other countries is necessarily injurious to the industry of the country wherein the capital has been created. I must not be supposed to be unaware of the contention that British investments abroad may help to provide Britain more cheaply with food or materials, or in other ways make foreign lands better customers for English goods. All I desire to make clear is that the proposition that all a Government can do by its legislation is to affect the application within the country of a predetermined quantum of capital is not tenable. It can indubitably, in some measure, influence, whether wisely or not, the quantum either of home-created or of foreign capital, or of both, devoted to production in a particular country.

In cases where there is no hint of protection by means of tariffs or subsidies to suggest alarm, this fact that Government can affect the quantity of capital employed is generally recognised. Thus, the desirability of encouraging an influx of foreign capital to England was one of the avowed motives of the Patent Act of 1907. Four years later it was asserted, apparently on official authority, that 'some fifty firms had commenced, or were about to commence, work under the Act, and that the new factories involved a total outlay of some 800,000*l*. It was hoped that employment would, in this connection, be found for 7,000 additional men, and that the wages paid to them would total something like 8,000*l*. per week.' [70] It may well be that these estimates were over-sanguine; but it does not seem to have occurred to anyone to deny that some attraction of foreign capital to England might reasonably be expected to take place, and that, so far as it did occur, it would be beneficial to England.

[67] *Report*, pp. 38, 39.

[68] This results from a comparison of Sir George Paish's calculation of 'Great Britain's Capital Investments,' in *Jour. Roy. Stat. Soc.*, LXXIV., p. 187 (1911), with the *Economist's* calculation of national wealth in Hirst's chapter added to Porter's *Progress of the Nations* (1912).

[69] Lavington, *The English Capital Market* (1921), p. 205.

[70] *Times*, March 23, 1911.

And one may go a step further. That, under certain circumstances, a tariff might have the effect of causing foreign manufacturers to set up works within the tariff walls has, for some time past, been illustrated by numerous and not unimportant examples; and English manufacturers have not been deterred from yielding to the pressure of foreign tariffs and establishing works abroad by any personal views of their own as to Free Trade or Protection.[71] They have often taken with them a nucleus of skilled English workmen.

But now, in recent years, various Governments have begun once more to take notice of the fact that tariffs do, under certain circumstances, cause foreign capital to be introduced, and to use it as part of the justification of a protective policy. I may give two examples. One can get from the Bureau of Commerce and Industry of the Commonwealth of Australia a long list of 'some of the British Manufacturers who have established interests in Works and Factories in Australia.' Among them will be found a dozen or more of the best-known English concerns. And the list is headed by the following notes :—

'(1) New names are being added to this list every week, and it shows that in the opinion of some of the most progressive British manufacturers it will pay to bring plant and skilled workers to the raw material in Australia . . . .

'(2) The new Australian Tariff is calculated to bring about the establishment of every natural and essential industry; and as the tariff affords real protection and opens up excellent prospects to the efficient, the next few years will see considerable industrial progress in Australia.'

I have no opinion as to the wisdom, in Australian interests, of its present tariff. I cite the case simply as showing how impossible it is now to speak as if the capital which a country can have for its manufactures must always be entirely accumulated within the country itself.[72]

The other case is even more significant. The new Irish Free State appointed last year a Committee of five Irishmen, of whom four were economists, to advise it as to its tariff policy. The Committee reported in what, with sufficient accuracy, may be called a free trade direction. But in that report occurred the following passage: 'The more complete the protection afforded by a tariff, the greater will be the inducement to outside competitors to retain their Irish market by coming inside the fiscal barrier and establishing factories in the Free State. And in the existing condition of industry the expenditure will be undertaken by very large industries in the hope of retaining even a small fraction of their existing market. . . . The new competitor will, it is true, in a sense establish an Irish industry and provide employment for Irish workers.'

All that the Committee find to say, by way of demurrer, is that 'in this case backward Irish industries will be faced by a home competition from a highly organised rival quite as serious as that from which they have sought to escape.'[73] That is to say, free trade must be maintained in the interests of 'backward Irish industries.'

[71] Some examples prior to 1903 are collected in my *Tariff Problem*, p. 77.

[72] This was Sir Robert Giffen's line of thought as recently as 1877. In his paper on Foreign Competition he argues that 'the amount of capital required to replace us even partially is so great that it must take many years *for our competitors to accumulate* any such amount' (*Economic Inquiries and Studies*, II., p. 429).

[73] *Reports of the Fiscal Inquiry Committee*, Dublin, 1923, § 126.

A century and a third before, Alexander Hamilton had thought it necessary to refer to a like fear of competition with the home producer: 'It is not impossible that there may be persons disposed to look with a jealous eye on the introduction of foreign capital, as if it were an instrument to deprive our own citizens of the profits of our own industry.' His own view was different: 'Instead of being viewed as a rival, it ought to be considered as a most valuable auxiliary; conducing to put in motion a greater quantity of productive labour and a greater portion of human enterprise than could exist without it.' [74]

The Government of the Irish Free State seems more inclined to follow Hamilton's lead than to be deterred by the prophecy of its Tariff Commission; for the Minister in charge of the measure which has lately been introduced into the Dail for 'a limited . . . experiment in the use of a tariff for the stimulation of Irish industry' [75] expressly mentioned the expectation of attracting capital from outside as one of the motives justifying the new departure. Here, again, I had better safeguard myself: as to whether a tariff on the particular commodities proposed is wise for Ireland I am not in a position to have an opinion; nor do I know how much non-Irish capital is likely to be attracted in these particular cases. I refer to this instance of Ireland simply as showing that not only the Irish Government but also its Committee of Economists are of opinion that legislation can have some influence on the amount of capital employed within the country.

I shall pass to more controversial ground if I refer to recent events in Great Britain itself. But it ought to be possible to state what, as far as one can make out, are assured facts without implying necessarily any opinion as to the policy with which they are associated. One is that the Swiss Chemical interests have been encouraged to enlarge considerably their plant in England since the Dyestuffs (Import Regulation) Act became operative in January 1921. The other is that the McKenna Duties have led some of the largest foreign manufacturers of motor-cars to establish works in Great Britain. They have usually begun with the importation of parts, and with merely assembling and finishing in Great Britain; yet even for that purpose large factories and many workpeople are necessary. In one important instance, manufacture has become almost entirely British. That the British preference on imports from the Dominions has had the effect of causing a certain transfer of American capital to this Dominion is, of course, well known to the Canadians in my audience.[76]

Perhaps some countries may be the better without imported capital and others without exporting it: perhaps the Governmental measures which influence the movement in either direction are ill advised, and we

[74] *Report on Manufactures*, p. 39.

[75] Dail Eireann: *Parliamentary Debates*, April 25, 1924, p. 42 (tobacco, boots, confectionery); 70 (jam), cf. the utterances of other Deputies; 127 (boots); 130 (tobacco); 155 (soap).

[76] As lately as 1887 Lord Farrar will be found arguing that the increase in wages paid and persons employed in Canada under its protective policy must have been due to 'a compulsory and artificial transfer of the labour and capital *of Canadians* from the industries in which they can produce more, to,' etc.: *Fair Trade v. Free Trade* (4th ed., 1887, p. 63). The investment of foreign capital, especially American, in Canada, awaits, I think, its historian.

may sigh for the uncomplicated simplicity of the time when every country used only, and used all of, the capital it had itself accumulated. But that is not the world in which we live.

7, 8. The next of the generally accepted propositions in the sequence we are now considering was this: that while the capital and labour within a country were quantities the amount of which no Government action could influence, they could readily be transferred from one industry to another within a country, if their previous employment were taken from them by imports. It is the doctrine of the Internal Transferability of capital and labour, as existing conditions rendering free trade always beneficial.

The history of the literary presentation of the idea is suggestive. Like so much else, it probably came to Smith from Hume. Hume, in seeking to remove the alarm lest the 'interference' of our neighbours with any of our staple trades could do us great harm, argues that 'if the spirit of industry be preserved, it may *easily* be diverted from one branch to another; and the manufacturers of *wool*, for instance, be employed in linen, silk, *iron*, or any other commodities for which there appears to be a demand.'[77]

From this statement Hume would probably not have been disposed to draw the sweeping practical conclusions of later writers;[78] yet here is the transferability idea in germ. Of the idea in relation to capital I have already said something. Let us fix our attention on labour; for 'manufacturers' here means manual operatives.

Hume was writing in 1758. The use of coke for smelting iron was only just beginning; none of the great inventions in the iron and mining industries had yet been introduced: neither puddling, nor rolling, nor the steam engine. The only textile industry to which 'power' had been applied was the relatively small silk industry; not one of the revolutionary changes in cotton spinning and weaving had been made, and the engineering and shipbuilding trades were far in the future. Moreover, Hume is specifically referring to 'the staple industries' of the country; and there may have been some justification in the pre-machine age for thinking that—except in the case of highly skilled artisan crafts producing luxury goods—labour could move pretty easily to and fro. Even so, the 'easy' diversion of workpeople from the textile industries to the iron manufacture rather suggests a literary man's unacquaintance with the actual conditions of working-class life.

Adam Smith, twenty years later, thought it necessary to argue the matter more at length. He makes four points.[79] The first is, that the soldiers and seamen disbanded at the end of the Seven Years' War were gradually absorbed in the great mass of the people and found work in a variety of ways, without any 'sensible disorder,' 'though they no doubt suffered *some inconveniency*.' 'To turn the direction of industry from one sort of labour to another' 'is surely much easier.' The second is that, 'to *the greater part of manufactures* there are other *collateral* manufactures of so similar a nature that a workman can *easily* transfer his industry from one of them to another.' The third is that '*the greater part of such workmen*

[77] Essay, *Of the Jealousy of Trade.* (Reprint, p. 197.)

[78] For he continued to print by the side of this Essay the preceding Essay in which he argued that 'a Government has great reason to preserve with care its people and its manufactures.'

[79] Bk. IV., ch. ii. (II., 43); italics added.

are occasionally employed in country labour.' And finally that, whatever happens, there will, in any case, remain the same 'stock' or capital in the country, and that this will employ an equal number of people in some other way.

Obvious comments may be made on each of these points. The use of a term like 'inconveniency'; [80] the use of the word 'easily' to describe transference even to 'collateral' manufactures; [81] the view that whatever particular home industry might be killed by foreign imports, 'the capital of the country remains the same'—a view so increasingly difficult to hold, as capital comes to be fixed in specialised plant; these points each suggest some evident reflections.[82] But it will be enough to dwell for a moment on the remarkable argument that 'the greater part of workmen in manufactures are occasionally employed in country labour.' In the age of 'domestic industry,' agriculture and manufacture were in truth often combined, in various ways, by the same persons or families; though one may doubt whether this was true of 'the greater part of workmen in manufactures' in England at the time Smith was writing. Need one say that the whole trend of development ever since has been away from such a combination, above all in England?

When we come to McCulloch, half a century later, there is an unmistakable change in the intellectual atmosphere. This country had in the interval entered, first of all the nations, into the machine and factory age; and, whether it was owing to that cause alone and the consequent cheapness of our commodities, or to other causes also, England had for the time a monopoly of the most important manufactures. The cotton industry, hardly existent in 1776, in 1825 was exporting goods to the value of much over 18 millions of pounds sterling. We had been, on balance, an iron-importing country; in the last three decades, imports had fallen by three-quarters, and exports had quadrupled. Accordingly, McCulloch could write quite in the strain of *Rule, Britannia!* Other nations might not be so blest, but *we* should flourish! Whatever 'loss and inconvenience' might follow a Free Trade policy 'in other countries,' 'our superiority in the arts is so very great, that only a very inconsiderable proportion of our population would be driven from the employments now exercised by them by the freest importation of foreign products.' [83]

Accordingly there was no need to alleviate possible apprehension by invoking the aid of occasional agricultural employment. Any residue of

[80] The word is echoed by Fawcett, *Free Trade and Protection*, p. 9: 'The loss and inconvenience which always accompany the transfer of capital and labour from one employment to another.'

[81] Smith did, at any rate, unlike Hume, limit the ease of transference to 'collateral' manufactures. T. B. Say—who, according to Ricardo, 'succeeded in placing the science' of Smith 'in a more logical and instructive order,' and had more influence on English writers than is now remembered—rivals Hume in his economic imagination. If, he says, France refuses to take English woollens, 'England will employ the same capital and the same manual labour in the preparation of ardent spirits by the distillation of grain that were before occupied in the manufacture of woollens for the French market.' (1803; English translation of 1820.)

[82] Smith on the next page recognises that that part of manufacturing capital 'which is fixed in workhouses and in the instruments of trade could scarce be disposed of without considerable loss.' He could not foresee how large a part this was destined to become.

[83] Part II., Section II. (Reprint, p. 76.)

doubt could be expeditiously disposed of by a piece of abstract argument, showing that, even in the improbable contingency that 'a few thousand workmen' lost their jobs through free imports, no harm would be done. For since imports must be paid for by exports, an amount of work *must* be called for to create them, 'equivalent' to that dispensed with. And this doctrine is asserted in its starkest form. There is no suggestion that the gain will be to the men already in those *other* trades which will now have larger exports, so that the nation would not suffer *as a whole*; or that the labourers now left idle will *ultimately* get absorbed. No; nobody is going to suffer, even for a short time. 'Suppose that, under a system of free trade, we imported a considerable portion of silks and linens now wholly manufactured at home. . . . It is obvious that *such* of our *artificers as had* previously *been engaged in our silk and linen manufactures*, and were thrown out of these employments, could *immediately* obtain employment in the manufacture of the products which must be exported as equivalents for the foreign silks and linens.'[84]

It was not for another half-century that an English economist who could get the ear of the public began seriously to consider how far the transferability of labour and the transferability of capital—which he justly described as 'the postulates of' the then current 'Political Economy'—were in fact true.[85] Anyone who looks at his *Economic Studies*[86] will observe that Bagehot gives much more attention to capital than to labour; and that, as to labour, he occupies most of his space in demonstrating that in earlier times and to-day in primitive countries labour is *not* transferable. But, for such a country as England is now, he thinks 'no assumption can be better founded.' Labour does not flow so quickly from pursuit to pursuit as capital does: 'but still it moves very quickly.' There are, he grants, even at present in England, many limitations to mobility. 'There is a "friction," but still it is only a "friction"; its resisting power is mostly defeated, and at a first view need not be regarded.'

Like so much else in actual industrial life the question of the extent of the mobility of labour has been subjected to very little quantitative investigation. But all who have come into close contact with the industrial population of the older countries will agree with me in feeling that 'friction'

[84] In the edition of 1843 (p. 151) for *immediately* is substituted *in future*. But it is still the discharged artificers themselves who find the equivalent occupation.

[85] Senior, as long before as 1835, had pointed out, with remarkable insight, that the mobility of labour was being lessened rather than increased by the industrial revolution. 'The difficulty with which labour is transferred from one occupation to another is the principal evil of a high state of civilisation. It exists in proportion to the division of labour.' As to capital, he anticipated recent writers by pointing out that 'those costly instruments which form the principal part of fixed capital can scarcely ever be applied to any but their original purposes. They are employed, therefore, in the same way, long after they have ceased to afford average profit on the expense of their construction, because a still greater loss would be incurred by attempting to use them in a different manner.'—*Political Economy* (in the series *Encyclopædia Metropolitana*), reprint of 1854, p. 217.

The disregard by subsequent writers of what one might suppose suggestive observations is curious when contrasted with the readiness with which Senior's Abstinence view of Interest and his sharpening of the Wage Fund idea were accepted. It was, perhaps, due to the failure of Senior to make any large theoretic use of the observations. And ideas which can be fitted into a prevalent general body of thought are more likely to be assimilated than disturbing ones.

[86] 1880, p. 21, *seq*.

is an inadequate and misleading term, and that, in any case, it is very necessary to go on to a 'second view.' Doubtless there is a considerable slow-movement mobility—the mobility of a glacier rather than that of a stream. It is chiefly exhibited in the inclination of young people (or their parents) away from obviously declining trades and towards such trades as happen to be within their reach where employment is supposed to be good. And then there are occupations—for instance, that of a carpenter—in which men can find employment in two or more alternative 'industries,' in the wider sense of that word now coming into use—for instance, in building proper or in shipbuilding. But the fact seems also to be that a workman with definite acquired skill seldom changes his occupation in a country like England; and I imagine this is the case also in the older countries of Europe. Even unskilled men, mere 'labourers,' seldom leave 'the industry'—in the wide sense of the term—with which they have been associated. This is the case even when better-paid and more regular work is in fact available in some other occupation: the reasons are to be found partly in inertia, partly in attachment to local ties, but also quite as much in the need, or supposed need, of acquiring new skill, and the difficulty as well as risk of doing so. And hence, when men become unemployed, they cling to their own trade in the hope of being taken on again, to an extent which is inconceivable to middle-class people. Still more is this the case when it is short time or lowered remuneration they are suffering from.

Some of the recent developments of industrial organisation and legislation in the older countries which most of us regard with satisfaction have for their effect to lessen mobility. This is the result, for instance, of trade unionism, among more or less skilled operatives. The assertion that 'trade unions increase mobility of labour' [87] is true as between particular shops and particular localities in the same industry: it is the reverse of true for adult workpeople who desire to shift from one industry to another. To say that certain trade unions do in effect impose obstacles to entry upon a trade is not necessarily to condemn them: it is but to state a fact. Unemployment insurance again, in a country where there are recognised standards of wages, is bound, if it recognises a claim to a certain standard on the part of unemployed persons, to strengthen the tendency of workpeople once in a particular trade to stick to it. The National Insurance Act of 1920 lays down that a workman is justified in demanding unemployment benefit and declining proffered employment if that employment is not 'suitable.' If employment is offered in the same district—as will often be the case—it can be refused if the rate of wages is lower or the conditions less favourable than in the employment in which the workman was before ordinarily employed. And there seems to be a natural tendency in recent decisions of the courts to allow specially trained or skilled men and women to refuse unskilled work, especially if it could be thought to endanger their return to skilled employment.

The effect which unemployment insurance may well have in this respect is more than hinted at in the comments of several of the Governments on the definition of unemployment recently proposed by a Technical Commission appointed by the International Labour Office at Geneva. That definition ran as follows: 'Unemployment may be defined as the condition of a

[87] Beveridge, *Unemployment*, p. 105, and Index under *Trade Unions*.

worker who is both able and willing to work but is unable to find employment *suitable to his qualifications and reasonable expectations.*' The implication of such a clause in a European country is indicated in the approving comment of the Government of Finland : ' Skill in a trade and the possibilities of remuneration depending thereon generally fix the reasonable expectations of a worker.' On the other hand, the Governments of new countries like Canada and South Africa are unwilling to recognise the claim which seems to be involved in ' reasonable expectations.' The explanation is that the industrial conditions are in fact very different. This is well explained by the Government of South Africa : ' In the Union, with the exception of clearly defined trades . . . workers do not confine themselves to specified occupations, as they do in older countries where occupations and industries are more sharply defined or firmly established.' [88]

In a work which is among the most outstanding products of English economic inquiry in the present century, and which has had powerful influence on English legislation, I find the sentence : ' Adam Smith and his followers were right in emphasizing the mobility of labour as the cardinal requirements of industry.' [89] In the table of contents this appears as : ' The demand of economists for mobility of labour.' Adam Smith and his immediate followers did indeed ' demand ' it, as itself a good thing in the interests of production. Later economists have sometimes been more cautious and have ' demanded ' it, but only as a postulate of their deductive reasonings, without committing themselves to an opinion as to its own merits. To assume its merits, without sufficient regard to contemporary conditions, and to base the establishment of a widespread governmental organisation upon this one ' demand,' is likely to lead to some disappointment with the results—as has been in the case with the British Labour Exchanges.

When a long-established industry in England has been seriously damaged —as has, of course, occurred again and again—by changes in foreign tariffs, it has, I think, seldom happened that it has entirely disappeared. It may permanently contract into narrower dimensions, and in the next generation its place in a particular town may be taken by another and newer industry. In this case its disappearance will have been attended by an amount of suffering and, what is worse, of demoralisation which ' friction ' hardly indicates. Or in another ten years it may have obtained new markets in other lands, and its output may be as large as ever. In this case we shall be told what an admirable thing is freedom in stimulating the enterprise of manufacturers and compelling them to improve their methods. That it sometimes does both, I do not dream of denying. But the deterioration of character which does so easily beset workpeople during protracted periods of unemployment or under-employment is at least as important a fact as the blessings of the subsequent rebound.

And there is this to be added that, just as the old doctrine of the national capital exaggerated its fluidity within a country when already invested in plant, and minimised its fluidity as between countries when newly created, so the doctrine of the national labour-force overestimated its transferability

[88] *Methods of Compiling Statistics of Unemployment.* Intern. Labour Office : Studies and Reports, Series C. Unemployment No. 7. Geneva, 1922. See pp. 9, 10, 11, 16.

[89] Beveridge, *Unemployment,* p. 216.

from industry to industry within an old country, and overlooked the possibility of its transference to the same industry in another country. The migration of skilled labour to carry on its old occupation in a protected country does not take place on so large a scale as the migration of fresh manufacturing capital. But it has taken place repeatedly and is taking place now. And whether we in England or any other of the older countries view the phenomenon with complacency or concern, it presents a different picture to our eyes from that which was present either to Smith or to McCulloch.

9. The last of the large ideas which characterised the period we are considering is the unique emphasis it laid upon cheapness to the consumer as the test of social policy. I shall not go beyond Adam Smith for this. I will only quote three well-known passages. In the first he says: 'In every country it always is and always must be the interest of the great body of the people to buy whatever they want of those who sell it cheapest. The proposition is so very manifest that it seems ridiculous to take any pains to prove it.'[90]

In the second, with the same crushing air of certitude: 'Consumption is the sole end and purpose of all production; and the interest of the producer ought to be attended to, only so far as it may be necessary for promoting that of the consumer. The maxim is so perfectly self-evident, that it would be absurd to attempt to prove it.'[91]

The third passage is a compact summary of the system he founded. It is that in which he speaks, as it were in passing, of 'the cheapness of consumption and the encouragement given to production' as 'precisely the two objects which it is the great business of political economy to promote.'[92]

I remember, when I was at Harvard, going, in the company of Francis Walker, to dine at the house of Edward Atkinson. None could know Atkinson without liking him; and we had personal reasons that evening for being interested in 'the Atkinson Cooker.' But all I remember of the economic discussion which followed the repast was Walker's snort of speechless protest when Atkinson explained that to buy in the cheapest market and sell in the dearest was to carry out the Golden Rule. I thought it was only a playful extravagance on Atkinson's part, but original. I had not read my Cobden then as I have since had occasion to do. I did not know that the identification which startled Walker out of his politeness forms the concluding paragraph of one of Cobden's great speeches.[93] I had forgotten, also, that moving passage in one of his pamphlets in which Cobden declared that, in place of many of the glittering mottoes of our forefathers, 'we must substitute the more homely and enduring maxim—*cheapness*, which will command commerce; and *whatever else is needful will follow in its train*.'[94]

Some of the criticisms one comes across of Cobden are, one must confess, a little hasty. As the organiser of the first Faculty of Commerce in a British University, I should be the last to deny the vast importance of

[90] *W. of N.*, Bk. IV., ch. iii. (II., 68.)
[91] Bk. IV., ch. viii. (II., 244.)
[92] Bk. V., ch. i. (II., 333.)
[93] Feb. 27, 1846.
[94] *Russia* (1836), in *Political Writings*, p. 125.

Price. And I by no means suppose that all the pleas for particular tariffs in order to keep up the workmen's standard of living have been well founded. All that I wish to say, after such a survey of a past period as we have been engaged upon, is that economic life has ceased to be as simple, if it ever were as simple, as those two great men, Adam Smith and Cobden, seemed to think it. It has not been so clear to the last half-century as it was to them that human well-being can be achieved by the application of one symmetrical cycle of principles. By the whole current of its industrial legislation the civilised world has protested against the all-sufficiency of cheapness. It has now embarked upon the double task of making a Living Wage a first charge upon the community and of giving Security a larger place in industrial life. This will be a harder business than to abolish old and often outworn restrictions on 'natural liberty.' Society has been so sorely disappointed in the hope that, if it sought first cheapness, all other needful things, like social peace, would be added to it, that it is in the mood to 'explore other avenues,' as the phrase goes—avenues as yet imperfectly charted.

SECTION G.—ENGINEERING.

A HUNDRED YEARS OF ELECTRICAL ENGINEERING.

ADDRESS BY

PROFESSOR G. W. O. HOWE, D.Sc.,

PRESIDENT OF THE SECTION.

This Section of the British Association, over which I have the honour to preside, is concerned with the whole field of engineering, civil, mechanical and electrical. Within recent years the great developments which have taken place in each of these branches have necessarily led to a high degree of specialisation, with the result that a man may have an expert knowledge of one branch but a very slight knowledge of the other branches; in fact, the scope of a single branch is now so extensive and the amount of research work being done so great that it is impossible to keep abreast of the developments in one's own special subject unless one concentrates upon it to a degree that leaves little leisure for cultivating other branches of engineering. These considerations influenced my choice of a subject for this Presidential Address. As an electrical engineer, I felt that I should be expected to deal with some branch of electrical engineering—indeed, I should not feel competent to discuss any other branch—but, in view of the facts to which I have referred, I decided not to deal in detail with any single section of the subject, but to review the past development and present position of the subject as a whole.

The time for such a review is opportune. William Thomson, afterwards Lord Kelvin, the only man who has ever been elected three times (in 1874, 1889, 1907) President of the Institution of Electrical Engineers, was born on June 26, 1824. He was closely associated with the British Association and for sixty years took an important part in the meetings. He was President of the Association at the Edinburgh Meeting in 1871, and was several times President of Section A. I wonder what the members of the organising committee of Section G would think if the President, in addition to reading his address, offered to contribute twelve papers to the Proceedings of the Section: this is what Kelvin did as President of Section A at the Glasgow Meeting in 1876. I can find no record of his taking any part in the proceedings of Section G, although his brother, James Thomson, was President of the Section at the Belfast Meeting in 1874.

If any one event can be regarded as the birth of electrical engineering, it is surely the discovery by Faraday in 1821 of the principle of the electromotor; that is, that a conductor carrying a current in a magnetic field experiences a force tending to move it. It is noteworthy that ten years elapsed before Faraday discovered, in 1831, magneto-electric induction; that is, the principle of the dynamo. Four years later, Sturgeon added the commutator or 'uniodirective discharger,' as he called it, and in 1845

Cooke and Wheatstone used electromagnets, which Sturgeon had discovered in 1825, instead of permanent magnets. It was during the years 1865 to 1873 that the shunt and series self-excited dynamo, using a ring or drum armature and a commutator of many segments, finally evolved.

The early workers in the field do not appear to have realised the intimate connection between the dynamo and the motor, for, although the principle was discovered by Lenz in 1838, it only appears to have become generally known that the same machine could be used for either purpose about 1850. The principle underlying the whole modern development of electrical engineering—viz., the generation of electrical power by a dynamo, its transmission to a distant point and its re-transformation to mechanical power by an electric motor—appears to have evolved about 1873. An interesting light is thrown on the subject by a paper read before the Institution of Civil Engineers in 1857 by Mr. Hunt on 'Electromagnetism as a Motive Power.' In this paper the possibility of driving electromagnetic engines—that is, electric motors—by currents derived from voltaic batteries was discussed in the light of Jacobi's discovery of the back-electromotive force in these machines. He concluded that power so generated would be sixty times as dear as steam-power, and that it would be far more economical to burn the zinc under a boiler than to consume it in a battery for generating electromagnetic power. The leading scientists and engineers who took part in the debate all agreed that electromotive power was unpractical and impossible commercially. William Thomson sent a contribution in writing which concluded with the following sentence: 'Until some mode is found of producing electricity as many times cheaper than that of an ordinary galvanic battery as coal is cheaper than zinc, electromagnetic engines cannot supersede the steam engine.' As S. P. Thompson says, 'Faraday's great discovery of 1831 notwithstanding, the real significance of the dynamo had not yet (in 1857) dawned upon the keenest minds of the time.' Six years before this, Thomson had suggested the experiment of driving a 'galvanic engine' from a thermal battery, and had stated the problem in terms which show that he already had a correct grasp of the theory of the efficiency of the electric motor.

It was at the Manchester Meeting of the British Association in 1861 that Charles Bright and Latimer Clark read a paper proposing names for the principal electrical units; the names were 'galvat' for current, 'ohma' for electromotive force, 'farad' for quantity, and 'volt' for resistance. This paper led to the appointment of the celebrated Electrical Standards Committee of the British Association, which, after six years of strenuous work, produced the system now adopted internationally.

One of the earliest applications of the dynamo was for lighting arc lamps in lighthouses; in 1863 Thomson, writing to a friend on the relative merits of the Holmes direct-current and the Nollet alternating-current lighthouse machines, says: 'Thus Nollet escapes the commutator, *a great evil*, and gets a flame which does not burn one of the points faster than the other. The reverse of each proposition applies to Holmes. *The commutator is a frightful thing* . . . the thing to be done at the requisite speed is appalling. However, Holmes does it successfully. But I believe it cannot be done except theoretically without great waste of energy and consequent burning of contact surfaces. . . . *But I believe a large voltaic battery will be*

more economical than any electromagnetic machine. I am not quite confident about this, but shall be so soon, as I am getting a large voltaic, and I shall soon learn how expensive its habits are, and multiply by the number required for a lighthouse.' This was thirty-two years after Faraday had discovered the principle of the dynamo.

In after years Kelvin lost his dread of the commutator and championed direct against alternating current on every possible occasion. In 1879, when giving evidence before a Select Committee of the House of Commons on Electric Light, he even assured them that there would be no danger of terrible effects from the employment of electric power, because the currents would be continuous and not alternating!

The fifteen years following 1863 saw a great development of the dynamo, and in 1878, when a paper was read before the Institution of Civil Engineers on the improvements introduced by Siemens, Thomson made a remark, following a suggestion by Dr. C. W. Siemens, that showed that he had by this time thoroughly grasped the possibilities. He said that he believed that with an exceedingly moderate amount of copper it would be possible to carry the electrical energy for one hundred or two hundred or one thousand electric lights to a distance of several hundred miles. Dr. Siemens had mentioned to him that the power of the Falls of Niagara might be transmitted electrically to a distance, and he need not point out the vast economy to be obtained by the use of such a fall as that of Niagara or the employment of waste coal at the pit's mouth. In his evidence before the Select Committee referred to above he gave an estimate of the copper required to transmit 21,000 horse-power from Niagara to a distance of 300 miles.

In 1881 Thomson returned to the subject in his Presidential Address to Section A at York and said, 'High potential, as Siemens, I believe, first pointed out, is the essential for good dynamical economy in the electric transmission of power.' He mentioned 80,000 volts as a suitable voltage. In a paper before the Section he developed the now well-known Kelvin Law of the most economical cross-section of the conductor. In 1890 the American promoters of the project for utilising the power of Niagara turned to Thomson for his advice, and he became a member of the Commission of Experts. He was throughout stubbornly opposed to the use of alternating currents; he wrote, 'I have no doubt in my own mind but that the high-pressure direct-current system is greatly to be preferred to alternating currents. The fascinating character of the mathematical problems and experimental illustrations presented by the alternating-current system and the facilities which it presents for the distribution of electric light through sparsely populated districts have, I think, tended to lead astray even engineers, who ought to be insensible to everything except estimates of economy and utility.' He was in a hopeless minority, however, in this view, and the Falls of Niagara were harnessed to two-phase alternators with an output of 3,500 kilowatts each. Kelvin was present at the meeting of the British Association held in this city in 1897, and shocked many people by saying that he looked forward to the time when the whole water of Lake Erie would find its way to the lower level of Lake Ontario through machinery; 'I do not hope,' he said, 'that our children's children will ever see the Niagara Cataract.' Although he was apparently very much impressed with the success of the Niagara system, he was not converted

from his allegiance to direct currents, for at his last appearance at the Institution of Electrical Engineers, in 1907, he said, 'I have never swerved from the opinion that the right system for long-distance transmission of power by electricity is the direct-current system.'

The development of the dynamo during the seventies and the simultaneous development of the incandescent lamp led to the general introduction of electric light during the eighties. Attempts to make incandescent electric lamps had been made as early as 1841, when de Moleyns patented one having a spiral platinum filament, and in 1847 Grove illuminated the lecture theatre of the Royal Institution with such lamps, the source of power being primary batteries; but it was not until 1878 that the commercial development of the incandescent electric lamp was begun by Edison and Swan.

One of the earliest complete house-lighting installations was put in by Kelvin in 1881. A Clerk gas-engine was used to drive a Siemens dynamo, a battery of Faure cells was fitted up, and every gas-light in his house and laboratory at Glasgow University was replaced by 16 candle-power Swan lamps for 85 volts. He had to design his own switches and fuses, etc., for such things were almost unknown.

For about twenty years the carbon-filament lamp held the field without a rival for interior illumination, and, although attempts were made to improve its efficiency by coating the filament with silicon, the plain carbon filament only gave way finally to the metal-filament lamp. One of the most interesting developments in the history of electric lighting was the Nernst lamp, which was introduced in 1897; the filament consisted of a mixture of zirconia and yttria, and not only had to be heated before it became conducting but also had to be connected in series with a ballast resistance in order that it might burn stably. The way in which these difficulties were surmounted and the lamp, complete with heater, ballast resistance, and automatic cut-out, put on the market in a compact form occupying little more space than the carbon-filament lamp was, in my opinion, a triumph of applied science and industrial research. The efficiency was about double that of the carbon lamp. About this time, however, a return was made to the long-neglected metal filament. The osmium lamp invented by Welsbach in 1898 was put on the market in 1902, to be followed two years later by the tantalum and tungsten lamps. The latter was greatly improved by the discovery in 1909 of the method of producing ductile tungsten and by the subsequent development of gas-filled lamps in which the filament can be run at such a temperature without undue volatilisation that the consumption is reduced in the larger sizes to 0·6 watt per mean spherical candle-power. This improvement of eight times as compared with the efficiency of the carbon-filament lamp has led to the gradual replacement of the arc lamp even for outdoor illumination. The arc lamp was introduced at about the same time as the carbon-filament lamp, the Avenue de l'Opéra having been lit with Jablochkoff candles in 1878. The open arc was developed during the eighties; the enclosed arc, giving long burning hours and thus reducing the cost of re-carboning, was introduced in 1893, and the flame arc in 1899. During the first few years of this century the flame arc was brought to a high stage of development and the consumption brought down to about 0·25 watt per candle-power, but the necessity of frequent cleaning to prevent the reduction of efficiency by dirt and the

labour of re-carboning have led to its abandonment in favour of the less efficient filament lamp.

Before leaving the subject of electric lighting I would point out that it is remarkable that the first great application of electric power should have been for the production of electric light, since it is probably the least efficient of all its applications. The overall efficiency of a small power station supplying a lighting load and having therefore a very poor load factor would not be greater than about 6 per cent. from coal to switchboard, the steam-engine being, of course, the principal offender. Of the total power supplied to and radiated from a carbon-filament lamp not more than about 2 per cent. was radiated as light, so that the overall efficiency from coal to light was 2 per cent. of 6 per cent., which means that of every ton of coal burned at the power station with the object of producing light all but about 3 lb. was lost as heat at various stages of the transformation. Even now, with up-to-date steam plant and gas-filled lamps, the overall efficiency from coal to light is not equivalent to more than 40 to 60 lb. of coal out of each ton. The electrical engineer may derive a little comfort from the knowledge that the purely electrical links are the most efficient in the chain.

Whilst on the subject of efficiency I might point out that the difference between the prices at which coal and electrical energy can be purchased by the ordinary citizen corresponds to the losses incurred in the power station; that is to say that the cost of the generation and distribution of the electrical energy is covered by the better terms on which the power station can obtain fuel. In Glasgow the writer pays 5*l.* per ton for anthracite to burn in a slow-combustion stove; taking the calorific value of anthracite at 9,000 kilowatt-hours per ton, which is equivalent to 14,000 British thermal units per lb., this works out at $7\frac{1}{2}$ kilowatt-hours for a penny. For electrical energy for heating and cooking purposes the writer pays a penny per kilowatt-hour. This ratio of 1 to $7\frac{1}{2}$ will correspond fairly closely to the overall efficiency of the power station. In view of the high efficiency and convenience of slow-combustion stoves, it is evident that electric heating cannot be expected to compete with them for continuous operation ; for intermittent heating the question is very different.

Returning from this digression to the development of the direct-current dynamo, it may be noted that the drum armature now almost exclusively employed was invented in 1872 by von Hefner Alteneck, and gradually displaced the ring armature of Pacinotti and Gramme. Although Pacinotti's original ring armature was slotted, smooth armatures were preferred for many years, until the mechanical superiority of the slotted armature caused the disappearance of the smooth core with its wooden driving pegs which were employed to transmit the turning moment from the conductors to the core. The commutator and brushes were a great source of trouble, but by the gradual elimination of unsuitable material and by better design and methods of manufacture the commutator has been made a most reliable piece of apparatus. The difficulties of commutation, and especially the need of continual adjustment of the brush position, were largely overcome by the invention of the carbon brush by Professor George Forbes in 1885. It should be pointed out that the commutating poles, which have come into use so much in recent years, were originally suggested in 1884, and are therefore older than the carbon brush.

The realisation of the idea of supplying electric current from a power station for lighting houses in the neighbourhood owed much to the energy and business ability of Mr. Edison. He exhibited his first 'Jumbo' steam-driven dynamo in 1881, and installed two sets at Holborn Viaduct in the following year to supply current to neighbouring premises. The output of these sets was about 90 kilowatts at 110 volts, which was so much larger than anything previously constructed that the name 'Jumbo' was applied to these sets. About 1890 the multipolar type began to replace the bipolar type for the larger sizes. The size of the single units employed in power stations gradually increased with the increasing demand, and by 1895 dynamos of 1,500 kilowatts had been installed.

As in all other types of machinery, the output obtainable from a given size has been gradually increased by improvements in the electrical, magnetic, and mechanical properties of the materials employed, and by improving the design so as to remove ever further the limits imposed by heating, sparking, voltage drop, etc. The freedom from trouble of the enormous number of electric trams and trains, to take only one class, is a testimonial to the reliability of the modern direct-current motor.

The alternator has had a more varied development than the dynamo, mainly because of the absence of the commutator. The necessity of keeping the brush gear stationary and accessible and therefore allowing the commutator and armature to rotate led to an early standardisation of type in the D.C. machine. In the alternator there was no such limitation, and whether the field system should be inside or outside the armature and which of the two should rotate were largely matters of choice. There are great advantages in having the armature, which usually carries a high-voltage winding, stationary, and the usual practice has been for the field system to rotate within the armature. The most striking and best-known exception is the umbrella type of alternator installed in the first Niagara power station, in which the field system rotates outside the armature. The design of alternators has been controlled to a large extent by the development of the prime mover. On the Continent of Europe the slow-speed horizontal steam-engine led to the construction of alternators of enormous diameter in order to get the necessary peripheral speed, the axial length being consequently reduced to a few inches. In several cases these machines reached such a height that the travelling cranes in the erecting shops were useless, and special tackle had to be erected in order to assemble the machines. In England the high-speed marine-type engine was generally preferred, and consequently the alternators had a smaller number of poles and a smaller diameter. All this has now been modified by the development of the steam turbine.

Ferranti was apparently the first to suggest that the power station should be outside the city, at a point convenient for fuel and water supply, and that the power should be transmitted into the city by high-voltage alternating currents. In 1890 he built the Deptford Station for the London Electric Supply Company, and installed 1,000-kilowatt 10,000-volt alternators. This was the pioneer high-voltage underground cable transmission, and much was learnt concerning the peculiarities of alternating currents when transmitted over cables of considerable capacity. The following year, 1891, saw the first long-distance transmission by means of overhead conductors in connection with the electrical exhibition at Frankfort-on-

Main; three-phase power was transmitted, at 8,500 volts, from a water-power station at Lauffen to Frankfort, a distance of 110 miles.

This development of the use of high-voltage alternating currents followed the development of the transformer. Gaulard and Gibbs patented a system of distribution involving transformers in 1882, and, although their patent was upset in 1888 on the ground of its impracticability, the present method of using transformers for the distribution of electrical power was introduced in 1885, and shown at the Inventions Exhibition in London in that year. Although from 1890 onwards there has been a steady increase in the size of alternators and transformers and in the voltage employed for long-distance transmission, the last few years have seen a really amazing increase in the size of the units employed. In 1913 the largest 2-pole turbo-alternators had an output at 3,000 revolutions per minute of about 7,500 kilowatts; such machines are now made up to 30,000 kilowatts, and 4-pole alternators are running at 1,500 revolutions per minute, with an output of 60,000 kilowatts. This increase in size and in peripheral speed has been made possible by improvements, both in the material and in the design. With a bursting speed 25 per cent. above the running speed, the peripheral speed can now be raised to 150 metres per second. Improved methods of cooling and a better understanding of the various causes of loss in the armature have enabled the materials to be used at higher current and flux densities.

This great increase in the size of units is not confined to the steam turbo-generator, as can be seen from the water-turbine sets recently added to the Niagara installation. Whereas the original Niagara turbines were of about 5,000 horse-power, the new ones have an output of 70,000 horse-power at the low speed of 107 revolutions per minute.

The importance of cheap electric power has led to this great increase in the size of the units in the generating stations. Any slight difference of efficiency between a 10,000-kw. and a 60,000-kw. alternator is of little importance, and would certainly not counterbalance the decreased factor of safety due to concentrating the whole power supply in three or four large units, instead of distributing it between a dozen or more units. The reason for the adoption of the smaller number of large units lies almost entirely in the decreased capital cost per kilowatt of plant. In my opinion, however, there are many cases in which too much consideration has been given to this factor, and too little to the importance of a guaranteed continuity of supply.

Of even greater interest than the growth in the size of the units in the power station is the development of the switch control and protective gear, which is such an essential element in the success of the modern power plant. In the early days of electrical supply all the switch-gear was mounted on slate panels in the engine-room; then, as the power and voltage increased, the switches were placed above, below, or behind the board and operated by mechanical links; then they were removed to another part of the building, each enclosed in its own fire-proof cubicle, and operated by means of relays. The modern high-power switch, like the transformer, is oil-immersed in its iron containing case, and is so robust and weather-proof that it needs no further protective covering, but can be placed in the open air. The insulated bushings through which the leads are taken into the case are the most vulnerable points, but constitute no insuperable difficulty at the present time.

The development of these robust and weather-proof switches and transformers has led to the introduction of the open-air sub-station in cases where alternating current has to be transformed from one voltage to the other, and there is consequently no running machinery. In generating stations also much of the controlling and transforming plant which was formerly housed in the building can now be placed outside, with considerable saving on the cost of the building.

In connection with the conversion of alternating to direct current, mention should be made of the mercury arc rectifier. Great improvements have been made in recent years, especially in Switzerland, and a number of high-power arcs have been installed in sub-stations. Although they have the advantage of doing away with running machinery, the modern rotary-converter is such a reliable piece of apparatus that it is very questionable whether it will be replaced to any considerable extent by the mercury arc rectifier.

Until recently, the only means of producing a large amount of high-voltage D.C. power was by connecting a large number of carefully insulated dynamos in series, as in the well-known Thury system of power transmission. Within the last two or three years another method has been developed, viz., the so-called transverter, which consists of an arrangement of transformers and a system of rotating brushes, whereby a three-phase A.C. supply is converted into an almost steady continuous current. The first apparatus of this type to be exhibited is installed at the British Empire Exhibition at Wembley, and is designed to deliver continuous current at 100,000 volts. It can also be used for the reverse process. It would thus enable a three-phase generating station and a three-phase sub-station to be connected by a direct-current transmission line, thus avoiding not only the maximum voltage of 1·4 times the effective voltage, which was one of Lord Kelvin's objections to the A.C. system, but also all trouble due to the capacity and inductance of the line. Whether the disadvantages of the transverter, when it is fully developed—it is yet in its infancy—will more than outweigh these advantages remains to be seen, but, apart from the transmission of power, the device may have many applications.

Electric traction represents one of the most important branches of electrical engineering. It shares with the petrol motor the distinction of having absolutely revolutionised the methods of transport within a single generation. In its origins it is nearly a century old, for attempts were made in the thirties to apply Faraday's newly discovered principle to the propulsion of vehicles, but, with very primitive motors and primary batteries, these attempts were doomed to failure. The development of the dynamo and motor in the seventies opened the way to further experiments, and at the Berlin Exhibition in 1879 a line one-third of a mile long was shown in operation, a locomotive drawing three cars. The first regular line was opened to traffic near Berlin in 1881 ; it worked at 100 volts and the current was collected from an insulated rail. Toronto was the scene of one of the earliest experiments in America; C. J. van Depoele, after some experiments at Chicago in 1882 and 1883, ran an electric locomotive in 1884 between the street-car system and the Exhibition in Toronto.

The difficulties were enormous. The carbon brush was not invented

until 1885, and commutation in a reversible motor with copper brushes caused great trouble; armature construction and winding was in its infancy; the suspension of the motor and the method of gearing it to the car axles were problems which were solved only after much experience. Rapid progress was made after about 1887, and the closing years of the century saw an enormous development, the elimination of horse tram-cars throughout the world and the electrification of a number of city and suburban railways.

Of the various systems of collecting the current, only two have survived for street-cars, viz., the usual overhead wire and the exceptional underground conduit; in the case of railways there is no necessity for a conduit and the conductor rail is carried on insulators above the ground-level.

Although 500-volt D.C. supply has been standardised for street tramways, the relative merits of D.C. and A.C. for electric railways has been a burning topic for over twenty years, and is now perhaps more burning than ever. It is somewhat akin to the battle of the gauges in the early days of steam railways, for it involves in many cases the problem of through running, if not now, in the not very distant future. Although the three-phase system was successfully installed in Northern Italy, it has grave disadvantages, and the battle now is confined between direct current at an increased voltage of, say, 1,500 to 2,000 volts, and single-phase alternating current. In the latter case there is, moreover, a further question as to the best frequency to adopt, this being usually either 25 or $16\frac{2}{3}$. The development of the A.C. commutator motor to the stage where it was applicable to traction took place during the first few years of this century, and, although in itself it is inferior to the D.C. motor, it introduces so many simplifications and economies in the transmission of the power from the generating station to the train that experts are very divided as to the relative merits of the two systems for main-line electrification.

I can only just refer to the applications of electrical power to chemical and metallurgical processes. Some of these are purely electro-chemical, others are purely thermal, while in many processes the electric current performs the double function of melting and electrolysing. The possibility of electroplating was discovered as early as 1805, but the commercial application of electro-chemistry on a large scale was impossible before the development of the dynamo. Within the last thirty years the provision of an abundant supply of electrical power has led to the creation of enormous electro-chemical industries; I need only instance the production of aluminium, carborundum, and calcium carbide. These industries have usually been established near a hydro-electric plant and provide a load of very high load-factor.

I turn now to what may be called both the earliest and the latest application of electricity; that is, its use for transmitting intelligence. One of the greatest factors in the development of our modern life has undoubtedly been the network of wires and cables which has spread over the whole earth, making possible an almost instantaneous transmission of intelligence and interchange of opinions. In the early days of electrical science the discovery of a new property of electricity was followed by attempts to utilise it for this purpose. As early as 1746 there are records of the use of frictional

electricity for the purpose, and distances up to four miles were tried. In 1774 Lesage of Geneva proposed 26 wires in earthenware pipes with pairs of pith-balls at the end of each wire, which flew apart when the conductor of a frictional machine was brought near the other end of the wire. A current of electricity was unknown until Galvani's discovery in 1789, and Volta's pile was first constructed in 1792. Carlisle in 1800 found that water was decomposed by passing the current from a Volta pile through it, and this was the basis of the telegraph proposed by Sömmering in 1809, in which 26 wires ended in 26 metallic points arranged in a row along the bottom of a kind of aquarium. By means of a lettered keyboard at the sending end the current could be applied to any wire, and a stream of bubbles caused to rise from the appropriate point, each point being duly labelled with its appropriate letter. The magnetic effect of the electric current was discovered in 1819, and immediately replaced the previous methods in efforts to develop an electric telegraph ; except for the attempts to make a high-speed chemical telegraph, all subsequent telegraph systems have employed the magnetic effect of the current. A great many of the fundamental inventions of telegraphy were made in the thirties ; the list includes the needle instrument of Cooke and Wheatstone, the sounder of Henry, the dot-and-dash inker of Morse, and the use of the earth as a return by Steinheil. Although the needle instrument is now obsolete, the sounder and Morse inker are still commonly employed. Many have been the devices for increasing the amount of traffic which can be worked over a single line, either by the simultaneous use of the line by a number of operators, as in the quadruplex and multiplex systems, or by punching the messages on paper tapes, which can then be fed into an automatic transmitter working at a speed ten to twenty times that attainable by a manual operator. In the most up-to-date systems the perforation of the tape is done by the operators working an ordinary typewriter keyboard, and the received message is printed in ordinary type, a single wire carrying eight messages simultaneously, four in either direction, at a speed of 40 words per minute.

The need for telegraphic communication between countries separated by water was so much the greater because of the slowness of other means of communication, but the difficulties in laying and maintaining 2,000 miles of insulated wire on the bottom of the sea must have appeared almost insuperable to the early workers ; fortunately, however, there were men who had the necessary vision and courage. The flimsiness of the early cables suggests that the pioneers underestimated the magnitude of the problem which faced them, which was perhaps fortunate. A cable was laid between Dover and Calais in 1850 ; it lived only a single day, but it was replaced in the following year by a successful cable.

The first cable was laid across the Atlantic in 1858, and, although in the light of our present knowledge we know that it could not have had a very long life, its failure after a few weeks of preliminary communication was primarily due to misuse owing to the ignorance of those in charge. Although much costly experience had been gained in the laying of cables in various parts of the world since this first attempt to span the Atlantic, the success of the second Atlantic cable in 1866 was largely due to the scientific ability of Kelvin and to his enthusiastic and untiring application to the project at every stage of the manufacture and laying of the cable. In addition to this, he not only designed the receiving instruments, but

superintended their manufacture in Glasgow and their installation and operation. The success of the Atlantic cable was to a large extent a personal triumph for Lord Kelvin. Although numerous improvements have been made in the details of cable manufacture and in the transmitting and receiving apparatus, no outstanding change has been made in recent years in the methods of submarine telegraphy.

Turning to another branch of electrical communication, it is no exaggeration to say that modern business life has been revolutionised by the telephone, which will shortly celebrate its jubilee, for it was in 1876 that Graham Bell invented the magnetic telephone receiver, although others, notably Reis, had been working at the problem since 1861. Bell showed his telephone in operation at the Philadelphia Centennial Exhibition in 1876, and Kelvin, who was one of the judges, brought one back with him and demonstrated it to Section A of the British Association, at its meeting in Glasgow in the autumn of 1876.

A successful telephone system requires much more than efficient transmitters and receivers, and the great development which has taken place has been largely a matter of improvement in the design of the many elements that go to make up a telephone exchange. The modern manual central-battery exchange, in which one has only to lift his receiver to call the operator and be connected in a few seconds to any one of 10,000 other subscribers, is a marvel of ingenuity and construction. But this is now gradually being replaced by the greater marvel of the automatic system, in which the operator is eliminated and the subscriber automatically makes his own connection to the desired subscriber. Attention should be drawn to two outstanding inventions in the actual transmission of telephony over long distances, viz., loading and repeaters. It was Oliver Heaviside who in 1885 proposed to improve the range by increasing the inductance of the line. Although this revolutionary suggestion fell on deaf ears for fifteen years, it ultimately proved to be one of the great inventions of telephony; it is of special importance in underground and submarine telephone cables, the electrostatic capacity of which otherwise seriously limits the range. The other outstanding novelty is the introduction of repeaters at intermediate points in long telephone lines. These repeaters are specialised types of low-frequency amplifiers; they were made commercially possible by the invention and perfection of the three-electrode thermionic valve. The attenuated speech currents arriving at the end of a section of line are amplified and thus given a new lease of life before being passed on to the new section. By using a large number of such repeating stations, telephonic communication has been established between New York and San Francisco. But in addition to making such long-distance communication possible, the use of repeaters enables medium distances to be bridged by relatively cheap lines of high attenuation.

One important application of telephony which is not generally known is in the control of transport; the advantage to be gained by controlling the whole railway traffic of a large district from a central office need only be mentioned to be appreciated.

Turning now to radio telegraphy and telephony, one cannot but marvel at the rapidity of its development and the inroad that it has made during the last two or three years on the domestic life of the whole civilised world. The theory of Clerk Maxwell in 1864 and the laboratory experiments of

Hertz in 1888 found their first practical application in Marconi's Italian experiments in 1895 and his demonstrations in England during the following year. Much of the rapid progress was due to his perseverance, vision, and courage in perfecting apparatus for short-distance work, and simultaneously experimenting over long distances, and thus, in the year 1901, settling by actual demonstration across the Atlantic the vexed question as to whether the waves would pass around the earth over distances of several thousand kilometres or go off into space.

The accomplishment of long-distance communication bristled with difficulties, largely due to unsuspected atmospheric effects which are still little understood; but such progress has been made and is continually being made that one dare not now adopt an incredulous attitude to the wildest dreams or forecasts of what is to be accomplished by 'wireless.' The commonplace facts of to-day would have appeared beyond the bounds of possibility ten or twenty years ago.

I have attempted to trace, in a necessarily somewhat superficial, but, I trust, none the less interesting, manner the development during the last hundred years of some of the principal applications of electricity to the service of mankind. In preparing this address, I have been greatly impressed by the enormous advances made, especially during the last thirty or forty years, in the mastery of man over the resources of nature, and in the use of these resources to the amelioration of the conditions of life. By the aid of electricity the energy of the coal or of the lake or river a hundred or even two hundred miles away is transmitted noiselessly and invisibly to the city, to supply light and warmth, to cook the food, to drive the machinery, to operate the street-cars and railways.

By its aid one can flash intelligence to the most distant part of the globe, hold conversations with friends hundreds or even thousands of miles away, or sit in one's home and listen to music and lectures broadcast for the entertainment or instruction of all who care to equip themselves with what may almost be regarded as a new sense. Whereas thirty years ago a ship at sea was completely isolated from the life and thought of the world, it is now in continuous communication with the land and with every other ship within a wide range.

In no branch of electrical engineering, however, is there any suggestion of having reached finality ; on the contrary, rapid development is taking place in every direction, and we can look forward with confidence to an ever-increasing application of electricity to the utilisation and distribution of the natural sources of energy for the benefit of mankind.

SECTION H.—ANTHROPOLOGY.

HEALTH AND PHYSIQUE THROUGH THE CENTURIES.

ADDRESS BY

F. C. SHRUBSALL, M.D., F.R.C.P.,

PRESIDENT OF THE SECTION.

A Canadian meeting of the British Association for the Advancement of Science is of special interest to Section H, since it was in this Dominion that it first entered upon a separate existence forty years ago.

In his Presidential Address to the Section at the Winnipeg Meeting, Professor Myres asked the question 'What happens to Englishmen in city "slums"?' or, in other words, how are the peoples of Britain adapting themselves to modern conditions? Are these conditions producing modifications in the racial constitution and qualities of the nation? The matter is one of importance to the older country, for over three-quarters of the population now reside in urban districts, and to the newer, since in the course of time industries must concentrate in favourable localities and close aggregates of population necessarily arise.

The trend of events can be followed in outline from demographic data from about the fourteenth century, though the records are scanty until the nineteenth century. The main factors are urbanisation and industrialism, the combined effects of which can be seen best, though in an exaggerated form, in those individuals who follow certain trades, such as the textile industry, which associate dense aggregation with, even at the best, unhealthy conditions of occupation.

Indoor trades and factory life introduce very different physiological conditions from those under which the young peasant has his being. These factors tend to depress the vitality of the incomer from the country, while those born in the industrial township would be exposed to urban conditions throughout early as well as adult life, and have the further handicap in infancy of the lack of care inevitably associated with the factory employment of the mothers.

In addition, selection may in time sensibly modify the distribution of the various racial elements of the population. Psychological factors, too, come into play, for some types seem to prefer the freer life of the open spaces and leave a district as it becomes more densely settled; while others, who have no love or aptitude for solitude, migrate into the growing towns. The early settlers of the North American continent were drawn largely from areas occupied by Nordic peoples whose early history was that of hunting and fighting communities. As the eastern edge of the continent became settled, it was this type that was largely represented in the pioneers of the West.

At first sight, the answers to the questions seem to be unsatisfactory, and it is common to hear of the physical deterioration of the people, though such pessimism is of long standing, being found as early as 'The Reflections of an Egyptian Sage.' It seems worth while to inquire if the change is real and permanent.

The most alarming data in regard to the position in Britain come from the Report of the Ministry of National Service on the findings of the recruiting boards during the last years of the European war. The recruits were graded into four categories, from those who exhibited the full normal standard of health and strength and a capacity to sustain severe exertion, through those with various partial disabilities, down to those totally and permanently unfit for any form of military service. The ages of those examined extended from eighteen to fifty, and the report therefore comprised such a study of a selected sample of a people as had never before been attempted. The survey of some two and a half million men showed them to be graded in the proportions [1] :—

Grade I.	..	36 per cent.
Grade II.	..	23 per cent.
Grade III.	..	31 per cent.
Grade IV.	..	10 per cent.

Grave disappointment followed this discovery; but a reassuring comment was made by the Commissioner for Yorkshire,[2] who pointed out that grading for military purposes must, in many essentials, differ from grading in respect to fitness for civilian life, which, after all, is the factor of most permanent importance to a nation. For example, an exaggerated flat foot might render a man useless for general military service, and yet for civilian purposes be of trifling import. The same would apply to many minor disabilities that increase with age. No previous data had given any idea of the extent of age changes in efficiency, though it was well known that the period of maximum efficiency in active games was the ages under thirty. It is therefore not surprising that the numbers fit for severe strain should fall off after that age or that relatively few over forty should be fit for effective military service. There is no reason to think that this is in any way a new phenomenon associated with urbanisation, or that a similar census in past centuries would have yielded any better results; indeed, data on health to be submitted on subsequent pages suggest that larger numbers of fit individuals at the higher ages exist now than in any past time. Another and more serious criticism of this report as an accurate survey of the whole state of the population of Britain rests on the fact that it was only undertaken after some years of war, when the physical pick of the nation had already voluntarily enlisted.

The more valuable data are contained in the records of some 260,000 youths born in 1900, about two-thirds of the total number attaining the age of eighteen in 1918, the proportion in their case being (in round numbers) [3] :—

Grade I.	..	65 per cent.
Grades II. & III.		30 per cent.
Grade IV.	..	5 per cent.

[1] *Report, Ministry of National Service,* vol. i., p. 4.
[2] *Ibid.* p. 109. [3] *Ibid.* p. 22.

These figures are nearer to expectations, although unsatisfactory for those who aim at 100 per cent. efficiency.

The proportions of Grade I. varied from 80-85 per cent. in rural areas, over 75 per cent. in mining areas, 72 per cent. in the suburbs around London, down to 49 per cent. in the crowded industrial areas of Lancashire. Some of the Scottish returns in particular indicate the price of urbanisation, at the ages of eighteen to twenty-one.[4]

—	Rural Agriculturists	Miners	Metal Workers	Small Towns	City
Grade I.	85·7	80·6	86·2	72·7	63
,, II.	7·9	9·3	8·2	13·2	17
,, III.	4·4	7·2	2·9	9·6	12
,, IV.	2·0	2·9	2·6	4·4	7

There is nothing in these figures to suggest that the British people have degenerated more than other nations. The German pre-war figures[5] showed 72 per cent. fit or prospectively fit for service and 28 per cent. less fit or unfit for service, with the same contrast between the rural and urban, the agricultural and the textile areas, as is noted in Britain; while the United States rejected 21 per cent. of their draft of men from twenty-one to thirty years of age.[6] In the latter country the higher proportion of rejections were from the urbanised and more industrial States, and the lowest from the more rural and sparsely populated areas of the West.

In general it may be noted that many of the causes of low grading at all ages were defects which would readily yield to treatment in their initial stages, and that great advantage would arise from the establishment of a social tradition in favour of early treatment, and in particular against septic mouths and uncared-for teeth. The younger members of the community are greatly in advance in these respects, and it is clear that the school, and its ancillary accompaniments, must now be reckoned among the most powerful of public health agencies.

Actual data on stature are very sparse in the reports of the recruiting boards; the figures are below those of the British Association Committee taken as a whole, but differ little if at all in those areas in which corresponding classes of the community can be compared, while the relation between physique and occupation is of the same order in the two reports. The Ministry returns show that a large number of the adult male population examined as conscripts in 1918 had statures between 64 and 67 inches, but the average figure obtained has little significance as an index of the whole pre-war population, since a large proportion of the tall stock had already enlisted. The returns from the United States[7] show that the average stature of the members of their draft who had been born in Britain was Scottish 67·9, English 67·7, a distinctly higher figure, probably to be explained by the greater tendency of the taller stock, the Nordic, to emigrate to fresh fields. The lowest statures quoted by the recruiting

[4] *Report, Ministry of National Service*, vol. i., p. 132.
[5] *Rep. Inter-departmental Committee on Physical Deterioration*, vol. iii., p. 56.
[6] 'Defects found in Drafted Men.' Washington.
[7] *Report of Medical Dept., U.S.A. Army*, vol. xv., Pt. I., p. 106.

boards were found among the casual labourers and the textile workers, who had been subject to bad conditions of environment.

The returns from the School Medical Service show that stature is on the whole greater in England and Wales to the south of a line drawn from the Severn to the Wash, with an extension northward to include Lincolnshire and the East Riding of Yorkshire ; in addition, scattered areas containing many tall children occur in Westmoreland, on the coast of Cumberland, in the far north of Lancashire, in the hilly districts of Staffordshire and in Merioneth. This line of demarcation clearly marks off the industrial from the rural districts, though it also largely coincides with areas of former Saxon, Danish and Norwegian occupation. The children in factory towns and mining areas are in general definitely shorter than those in rural districts. Arthur Greenwood,[8] considering the returns from a large number of education authorities, found that the results could be expressed in terms of those for all England and Wales with the following results :—

All England and Wales	100
Rural parts of County Areas	102·4
Urban parts of County Areas	100·5
London	99·6
Manufacturing Towns :	
Glamorgan and Monmouth (Coal and Iron Towns)	98·5
Yorkshire Woollen Towns	98·1
Lancashire Cotton Towns	98·0
Staffordshire Pottery and Hardware Towns	98·0
Durham and North-East Coast (Coal and Iron)	96·6

These findings agree closely with those of the recruiting boards, and a comparison of the two shows that the inferiority in the textile towns becomes more noticeable after the school age. In London[9] the physique is best on the whole in the suburban areas on the higher ground, and is worst in the poorer districts to be found in the central areas, along the Thames flats and in the valleys of the small streams that once flowed across the site of the present county. In Scotland the best physique is to be found in the rural areas, except in the Western highlands and islands where environmental factors other than urbanisation have tended to stunt growth and the racial type differs. As in England, industrial districts are below the average.

The best physique is found in the great public schools, then in order come the secondary schools, the trade schools and the ordinary elementary schools ; these correspond pretty well to the leisured and professional, the commercial, the artisan, and the factory and labouring classes, respectively. The stature of the children from the better-class schools, many of whom present Nordic traits and all of whom have been brought up in a favourable environment, is equal to any in the world. The general average for all types of schools is, however, below that of the children of British descent in the Dominion or the Commonwealth. The advantage of the latter supports the opinion that the emigrant stocks from Britain contained a large proportion of Nordic elements, and also suggests that the children flourish under the new environment.

[8] Greenwood, *Health and Physique of School Children*, pp. 27-28, and Appendix A.
[9] *L.C.C. Report of Medical Officer* (*Education*), 1910, pp. 131–133.

Even the worst estimates of the present-day physique, when compared with such records as exist of the former inhabitants of the British Isles, afford little evidence of a deterioration of stature in members of a particular racial type, but rather of a change in their relative proportion in the total population. In neolithic times, so far as can be gleaned from skeletal remains, the average stature of adult males was about 63 inches with a few taller individuals interspersed, who were perhaps of the ruling caste ; the Saxons averaged about 66 inches, the Norwegians and Danes were a little taller. The stocks in each district remained in comparative isolation until the advent of roads and railways and the demand for labour in new areas caused a greater degree of intermixture. Even now, rural areas which had originally a predominant Nordic occupation contain a taller and fairer population ; in the cities the degree of intermixture has proceeded to such an extent that there is relatively little relation between stature and hair colour. Throughout the mediæval period, stature remained little affected so far as can be judged from clothes, implements and armour, which would suit the larger number of the present-day people and would indeed be too small for the better built. In the eighteenth century there were many recruits whose stature was only about 63 inches.

Records of children of Lancashire operative and labouring classes, taken in the second quarter of the nineteenth century, when compared with similar figures at the present day show little change until the last few years. Since the initiation of the School Medical Service, it has become evident that a gradual improvement is in progress. In London elementary schools there has been a gain of a full half-inch in stature since 1904, while in the public schools average gains of an inch or more are recorded. The changes in weight are even more general and significant. It is noteworthy that the average weight of the crews in the Oxford and Cambridge boat race, who were always chosen from the pick of the undergraduates, has increased nearly a stone in the last sixty years.

Comparisons which have been made between children who have suffered from illnesses and those who have had none of importance, show the greater stature of the latter class and indicate one of the ways in which urbanisation exerts malign effects and also the advantages of care in childhood. Many children fail to attain their full stature on account of morbid factors which may act on the growing bones directly, as in rickets, or indirectly through malnutrition resulting from infectious ailments, catarrhs or actual privation. The predominant factor in the determination of stature is of course heredity, but where the soil and climate are unpropitious and poverty prevails the physique of all the inhabitants is depressed irrespective of their racial type. Collignon and others have shown that those removed from such districts in early life recover their normal stature, while those brought into the unfavourable surroundings are proportionately dwarfed.

Taking a more general survey, the health of a people under varying conditions may be measured by the variation in the duration of life as to which data are available for recent years and to some extent for the past. The duration of human life appears to have steadily increased from the earliest times. So far as can be judged from skeletal relics, early man did not live much beyond early adult life, though some individuals, such as the old man of Cromagnon, attained to old age. The words of the Psalmist

suggest that in his time the duration of life of those who survived the vicissitudes of infancy and early adult life was much the same as at the present day. The great gain has been that more now live to middle age or beyond. Macdonell and Pearson analysed the data on mummy cases from the time of the Roman occupation of Egypt [10] and the 'Corpus Inscriptionum Latinarum' of the Berlin Academy,[11] which gives the age at death of some thousands of Roman citizens who had lived either in the City of Rome or the provinces such as Africa, at the early part of the Christian era, and were able to construct rough life tables indicating the probable expectation of life at different ages. These may be compared with tables constructed by Halley on the data in the bills of mortality of seventeenth-century Breslau, by Milne for eighteenth-century Carlisle,[12] and with those constructed on modern census and registration data.

AVERAGE EXPECTATION OF LIFE FOR EACH PERSON LIVING AT THE BEGINNING OF THE AGE INTERVAL, IN YEARS.

Place and period	Roman Egypt	Imperial Rome	Roman Africa	Breslau 17 Cent.	Carlisle 18 Cent.	London[13] 1920-1922
Age						
0–	?	?22	??47	33	39	56
5–	31	24	45	41	51	59
15–	23	22	38	37	45	51
25–	23	20	34	30	38	42
45–	16	19	25	19	25	26
65–	10	12	15	10	12	12
85–	6	8	11	4	4	4

The results show such an increase in the expectation of life at the earlier ages as to emphasise Karl Pearson's comment on the Egyptian data: 'either man must have grown remarkably fitter to his environment or else he must have fitted his environment immeasurably better to himself.' Even in the early days, however, the disadvantages of the more urban surroundings are evident in the lower span of life in the Imperial City as compared with the Roman provinces. That a similar difference existed in the British Isles is certain, though from lack of data detailed comparison is impracticable until the last century.

The expectation of life varies from class to class much as does physique, being greater for the professional classes than for the agriculturist, for the agriculturist than for the miner, while the latter in turn is a better life than the tailor or the textile worker. From life tables based on the mortality experience of the years 1911-12, the expectation of life appears to be greater in the South than the North of England and to vary in each area with the degree of industrialism and urbanisation. It also seems when the data as to numbers of survivors are plotted on a map that there is a greater expectation in those areas which, at any rate until recent times, were occupied by a predominantly Nordic population.

[10] Pearson, K., *Biometrika*, vol. i., pp. 261-264.
[11] Macdonell, W. R., *Biometrika*, vol. ix., pp. 366-380.
[12] Pearl, R., *Biology of Death*, pp. 79-101.
[13] Unpublished data by courtesy of B. Spear.

Expectation of Life in England and Wales, 1911-1912.[14]

MALES.

Age	Area			
	London	County Boroughs	Urban Districts	Rural Districts
0·	49·5	47·5	51·9	56·3
5·	55·3	54·7	57·6	60·2
15·	46·8	46·3	49·0	51·4
45·	22·5	22·2	24·1	26·3
65·	10·5	10·0	10·8	11·9
85·	3·6	3·5	3·6	3·6

General health has often to be estimated from the records of mortality, though it must be remembered that morbidity is much greater than mortality and that the after-effects of injury or disease may long affect the physique of the sufferer. Lethal agencies are sometimes local, sometimes widespread in their action, and may at times exert a selective action on the population affected. Tertullian long ago maintained that earthquakes and wars, famine and pestilence have to be regarded as a means of pruning the luxuriance of the human race. These vary greatly in their mode of action and powers of selection. Earthquakes need not be considered so far as England is concerned during the historic period.

War in early culture might occasionally wipe out a whole population, but more often the skilful and strong survived; in modern war the selection favours those whose physique does not permit of active military service and is thus opposite in tendency. This indeed has been offered as a partial explanation of the poorer physique recorded of those French conscripts who had been born during the wars at the beginning of the last century, when the fittest of the adult male population were absent or killed. War acts more lethally through the social disorganisation, and the consequent famine and disease, which follow in its train, than through any casualties in the field; from these direct experiences on its own soil, England had been singularly free since the Norman period. Philip de Comines remarked 'England has this peculiar grace that neither the country, nor the people, nor the houses are wasted or demolished; but the calamities fall only on the soldiers and especially on the nobility.'[15] The wider effects of war were only felt, and then but locally, in the campaigns of the Stuart reigns, though there was great suffering earlier in the forays on the marches of Wales and Scotland. Thanks perhaps to the great demand for labour and to the separation allowances, as well as to the seat of action being abroad, the recent war has exerted no obvious harmful effects. The children have been well nourished and there was no great increase of defective children, such as had been anticipated by some, even in the areas most exposed to air raids. There was, it is true, an increase in the number of children who were troublesome and educationally

[14] *Supplement to 75th Annual Report of Registrar-General of England and Wales*, Part II., p. 34.

[15] Philip de Comines ed. Godefroy, *Mémoires, III.*, p. 155. Quoted by L. Creighton, *Hist. of Epidemics in Britain*, vol. i., p. 224.

backward, but on examination it was clearly seen that these features were not due to innate characters but to truancy and lack of discipline during the absence of their fathers.

Famine took its toll in Western Europe in the mediæval period, but England was the country in which the mass of the people soonest attained to fairly constant comfort. A poem, attributed to Henry of Huntingdon, contains the stanza:

> 'Anglia terra ferax et fertilis angulus orbis
> . . . .
> Externas gentes consumptis rebus egentes
> Quando fames laedit, recreat et reficit.'[16] [17]

This was a great contrast to France, which repeatedly suffered from long years of famine, but England certainly had occasional periods of scarcity at long intervals. Creighton,[18] it is true, draws attention to a mediæval saying 'Tres plagae tribus regionibus appropriari solent, Anglorum fames, Gallorum ignis, Normannorum lepra'; probably, however, the English were so used to good feeding that they indulged in the national habit of grumbling over a scarcity that elsewhere would have been taken as a matter of course. The 'Vision of Piers Ploughman'[19] seems to bear this out:

> 'And tho wolde wastour nouzt werche, but wandren aboute
> Ne no begger ete bred that benes Inne were,
> But of coket or clerematyn or eles of clene whete:
> Ne none halpeny ale in none wise drinke,
> But of the best and the brounest that in burghe is to selle.'

While Harrison in his 'Description of Britain'[20] quotes a Spaniard in Queen Mary's day as saying 'These English have their houses made of sticks and dirt, but they fare commonly as well as the king.' In modern times the only state of affairs which could be compared with events in the mediæval period is the Irish potato famine, in which actual starvation was accompanied, as of old, by outbreaks of fever and an abandonment of effort from sheer despair. In general any morbid influences on nutrition arose rather from a seasonal scarcity of certain essential articles of diet than from famine in the ordinary acceptation of the term.

Disease, throughout the historic period, must have been the most lethal of all the morbid agencies. There is nothing to suggest that there are important diseases to-day from which our ancestors were free, with the possible exception of syphilis, which is first recorded at the very end of the mediæval period. Anglo-Saxon leechdoms reveal that there were then, as now, cancer and consumption, gout and stone, the falling sickness and St. Vitus' dance, fevers, catarrhs and rheums. Even congenital defects were noted, Giraldus Cambrensis[21] in his 'Topographia Hiberniae' referring to the many individuals who were born blind, lame, maimed or having some

[16] *De praerogativis Angliae.* Quoted by Higden, *Polychronicon*, Rolls ed., ii., 18.
[17] Creighton, *l.c.*, vol. i., p. 8.
[18] *L.c.* vol. i., p. 52, with reference to Fuchs *Das heilige Feuer im Mittelalter* Hecker's *Annalen*, vol. 28, p.1. This latter cites *Alberici Chronic.*, Bouquet, xii., 690.
[19] William Langland, *Piers the Plowman*, passus vi., l. 304-308. Skeat's ed., p. 77.
[20] William Harrison, *Elizabethan England*, the Scott Library edition, p. 114.
[21] Rolls ed., vol. v., p. 21.

natural defect. On the other hand, certain of the scourges of our ancestors have practically disappeared, especially some of the infectious diseases. Leprosy and plague long ago ceased their ravages, typhus and famine fever vanished, save for isolated cases in later Victorian times, enteric fever has lessened nearly to the vanishing point, and even infantile diarrhœa is becoming less year by year. Most, if not all, of these diseases may be communicated by animal agencies, either by direct inoculation from bites or by secondary contamination. The louse, the bug and the flea, common until recent years, are succumbing to the newer tradition and meaning of cleanliness which has followed universal education, the medical inspection of scholars, and the action of public health authorities; the fly, an indirect agent, is being eliminated by improved sanitation, and the gradual disappearance of horse transport in our cities. As the changes proceed more rapidly in the towns the approximation of their health conditions to those in rural areas follows.

Epidemic diseases have always attracted more notice from the historian owing to the wide extent of the resulting evils, so that much is written concerning the plague, the sweat, gaol fever and smallpox compared with more common disorders of life. Some of these have appeared in earlier days to exert some selective influence, though this selection depended rather on the mode of transmission of the disorder. Any disease transmitted, whether by vermin or from case to case, would be more prevalent under conditions in which the population were closely massed, and at periods or under conditions in which either the facilities or the sentiment for cleanliness were lacking. The plague, save in its first pandemic outbursts as the 'Black Death,' was mainly a disease of the poorer classes in the towns, in each epidemic affecting especially the worst housed, worst fed and least cleanly. Sporadic outbursts in rural areas followed the introduction of infection from without, as was well recognised by villagers who forcibly endeavoured to prevent the entrance of travellers from affected areas. Gradual changes in habits and domestic furnishing which reduced the breeding-places of rats and fleas were followed by the extinction of the plague. The sweat, it was noted in Tudor times, differed in its incidence;[22] Kock said of the 1529 pandemic 'the poor people and those living in cellars and garrets were free from sickness,' while Renner noted 'it went most among the rich people.' This tradition, or a continuance of similar phenomena, must have remained, for we find in 'Measure for Measure'[23] Mistress Overdone says, 'Thus, what with the war, what with the sweat, and what with the gallows, I am custom-shrunk.' It was noted over a long period that whereas typhus, gaol fever, and the like were always present among the poorer classes, the greater mortality followed outbreaks among healthier individuals, who had lived an open life, such as soldiers brought back to barracks after a campaign in the field, sturdy felons newly flung into gaol, or, as in the Irish famines, magistrates and relief workers whose duty carried them into the haunts of the disease. In the case of the 'Black Assizes,' when judges and jurors succumbed but the prisoners escaped lightly, the phenomenon was ascribed to the latter being inured to

[22] Creighton, *l.c.*, p. 268, with reference to Gruner, *Scriptores de sudore Anglico superstites*, pp. 444-448.

[23] Act i., Sc 2

the stenches of the cells, though the modern explanation would suggest that they might have acquired immunity from previous and possibly slight attacks. It has been argued that such epidemic diseases served a useful purpose in that they removed weaklings, but the type selected by this test of relative immunity to typhus or gaol fever is not one to be commended on account of its mental or physical traits. The general statement is however open to doubt; Ballard [24] reporting on the Leicester outbreak of infantile diarrhœa in 1881 stated, 'Our experience of these epidemics by no means supports an opinion commonly held that a summer diarrhœa makes its first fatal swoop upon the weakliest children.' While the alleged benefits to the community of this mortality are neither uniform nor undoubted, the evil effects of infectious disease are very real, for it is a matter of common observation that the effect of these illnesses, especially in children, is to lower the vitality and reduce the physique sometimes even permanently.

In endeavouring to trace the changes in mortality in England it will be noted that in early days all is expressed in vague terms, *e.g.* that in the days of the Black Death 'a fifth part of the men, women and children in all England were consigned to the grave'; [25] occasionally a local chronicle records of certain years that the burials greatly outnumbered the christenings, but definite information only begins with the London bills of mortality in late Tudor times. From them we learn that in the liberties of the City, within and without the walls during the great plague years, the mortality ranged from 200 to over 400 per 1,000 living, and that in healthy years, which were few, the rate was some 60 per 1,000. The subsequent history of London is one of steady fall of mortality, though the greatest change has occurred in our own lifetime. In the latter part of the seventeenth century the rate was 80 per 1,000 living, in the eighteenth century it was 50, by the middle of the nineteenth century it was only 25, and since 1875 it has fallen rapidly to the present rate of 11-12 per 1,000. Some part of this change is due to variations in the age and sex constitution of the population at risk, but even when all corrections for this have been made, the mortality rate in England and Wales has fallen over a third since the beginning of registration in 1838.

A great part of this reduction has been in the infant mortality, which is perhaps the most important from the standpoint of potential parenthood. This mortality in early years was very high: thus in 1754 the deaths in London of children under two years of age were 45 per cent. of the deaths at all ages. Since the period of registration the infant mortality oscillated around 160 per 1,000 until 1900, since when it has fallen to 60 per 1,000 in 1923. The great part of the fall has been in deaths due to infectious diseases and diarrhoea; there has been little or no change in the rates from congenital defects or developmental disorders, which have remained relatively unchanged in all classes of the community, so that this lethal selection against the naturally unfit remains as rigid as ever. The fall in the mortality rate has been ascribed to various features: cleaner milk, fewer flies, the disappearance of the old feeding-bottle, and it seems to be most certainly connected with increased skill in maternal care. Thus

[24] Ballard, *Report of Local Government Board*, 1889, p. 43.
[25] *Eulogium Histcriarum*, Rolls ser., No. 9, III., 213.

it arises that the better spaced out the children are, the more survive. It is also significant that the change should have come about in the second generation of universal elementary education, suggesting the possibility that when the influence both of grandmother and mother is exerted in the direction of the sentiment for cleanliness inculcated in the school, the child reaps the benefit.

The mortality in the early years of life is greater in the cities than in the small towns and in these than in the rural areas ; it is greater in the north than in the south for all classes of the community, but it must be noted that with the great fall in the present century the gap between urban and rural areas has been closing. This again suggests that education and a higher standard of personal hygiene are important factors, for the country is always more conservative in its actions and beliefs. In the same way, comparing the social classes, the death rate is lowest in the upper classes, particularly among the children of professional men, and the agriculturists, but highest among the unskilled workers and the miners. This indicates that the influence of custom as well as the direct effects of urbanisation may be factors to be considered.

Special causes of morbidity are to be found in each of the main classes of workers. The mortality of the infants of agricultural labourers is below that of those of any other class of manual workers, not only as far as diarrhœal diseases are concerned—here, perhaps, they have better chances of obtaining fresh milk—but also from measles, tuberculosis and respiratory diseases generally. Some of the difference may be due to the rural child, on the average, being older than the townschild at the time he is attacked by infections ; for, whereas infantile infections spread through towns about every second year, in the country districts there may be an interval of five years between periods of epidemic prevalence. The infant mortality among textile workers is especially due to diarrhoea,[26] which may be ascribed in many instances to artificial feeding during the mother's absence at the mills. The children of this class also die notably from congenital malformation and prematurity, which might naturally have been attributed to the mothers working until a late stage of pregnancy, were it not that the mortality from these causes is even higher among the children of miners, whose women seldom work outside their own homes. The general infant mortality among the miners is higher even than among the unskilled and casual labourers in the towns, and if diarrhœa, gastritis and convulsions be taken together, their death rate from these causes is he highest of any class. In the Glamorganshire coal-fields the standardised child mortality in 1911 was 217 per 1,000 births for miners, and 176 for the rest of the workers in the area.[27] This may be due to improper feeding, to insanitary conditions, or possibly expresses some difference in traditional methods of infant care ; though it should be noted that as the miners have the larger families there must be less individual attention available for each child.

On the whole the evidence goes to show that morbidity, and especially infant morbidity, is closely associated with the aggregation of population,

[26] Various Annual Reports of Registrar-General, England and Wales, and especially Supplement to 75th Annual Report.

[27] *Census of England and Wales,* 1911, vol. xiii., pt. ii., table li.

but that in recent years improved standards of social or individual hygiene and comfort have done much to neutralise specific causes of ill-health. It may also be taken as proven that such ill-health is the greatest cause of stunting of physique. As in the past the countryside has been freer from these morbid influences, the country-man has been the physical superior of the townsman, comparing class with class.

There are three main ways in which the growth of towns and of the industrial system has prejudiced the health and thus the physique of the nation: adverse conditions of work which had little influence prior to the eighteenth century, unhygienic housing and bad feeding, which in varied ways have exerted their effects throughout a large part of human history. Some of these would be peculiar to the town, others would fall indifferently on town and country, and on all social classes save perhaps the very wealthiest, though even they could not entirely escape. The contrast is less vivid than would appear at first sight: the country child can get fresher food, it is true, but less of it perhaps, owing to the lower wages of his parents, though he often eats margarine, the butter being sold in the towns; he gets fresher air outside but not indoors, since the country cottage may be as dark, ill-ventilated and overcrowded as any in a city court.

The greatest change in the conditions of work was the rise of the factory, involving long confinement in monotonously ventilated rooms, as opposed to work in the open at the door of the home. Industrial centres may have been established in Roman times, but thence after for a thousand years and more they did not exist, and agriculture was the only important industry. The only factories were the local wind- or water-mills; there were local industries in cloth, linen or metals, but the great centres of to-day were non-existent.

The early factory was an extension of the home. Ure said: 'The workshop of the weaver was a rural cottage, from which when he was tired of sedentary labour he could sally forth into his little garden and with spade or hoe tend its culinary productions.' [28] Woollen weavers practised agriculture as a by-employment as late as the early part of the last century. The introduction of water- and steam-driven machinery aggregated the populations into the northern towns which arose near the sources of the power, and put a premium on the employment of children who could then do work which formerly required a man's strength. When local supplies ran short, children were procured from workhouses, even from as far off as London. Hunt, in his 'Political History of England,' [29] says: 'From little more than infancy they laboured for long hours, thirteen or more a day, in rooms badly ventilated and injurious to health. They were half starved and cruelly punished. Such of them as survived the prolonged misery and torture of their early days, grew up more or less stunted and deformed men and women, physically unfit for parentage, morally debased, ignorant and brutalised by ill-treatment.' The mills were hotbeds of 'putrid' fever, and the morbidity and mortality rates were appalling. In recent years the general hygiene of the worker, together with the removal of industrial risks, has made enormous strides, the result being apparent in the falling death rate and the healthier children.

[28] Ure, *Cotton Manufacture of Great Britain.*
[29] Hunt, *Political History of England*, vol. x.

So far as housing is concerned, in early days the English dwelt scattered through woods and marshes; in mediæval times they began to flock to the towns in which the sanitary conditions were bad; though regulations have existed even from Plantagenet days for the abatement of nuisances,[30] *e.g.* the prohibition of the erection of pigsties in the streets of London. In the late mediæval period there were narrow streets with overhanging upper stories so that light rarely entered the lower apartments.[31] Indoors, even in the great houses, the floors were covered with rushes piled, according to Erasmus,[32] the new on the old for twenty years without clearance: an excellent breeding-ground for vermin. Sanitation was perhaps a little, but not much, better by Stuart times; and, 'whatever sanitary gains may have accrued from the destruction of the City in the Fire, London in the late seventeenth century was an ill-conditioned place of residence, with hardly the rudiments of sewerage or water supply, and no systematic removal of refuse.' [33] In many years the burials outnumbered the baptisms and the town fed on the country. In Hanoverian times matters, if anything, deteriorated owing to the most unhygienic window tax; this, however, affected the country perhaps as much as the towns, for Howard [34] refers to 'farmhouses where the labourers are lodged in rooms that have no light or fresh air; which may be a cause of our peasants not having the ruddy complexions one used to see so common thirty years ago.' During the industrial revolution the aggregation of houses and the pollution of the air greatly increased and produced their well-known evils, though the sanitation of the individual houses was, in some respects, no worse than before. London lost its evil pre-eminence in the matter of mortality which was transferred to the manufacturing towns of the north, in which diarrhœa attacked the infants, and fevers of all kinds their elders. In the late Victorian period conditions steadily improved, although in remoter districts matters change so slowly that some of the present-day crofters' huts in the Outer Hebrides closely resemble the habitations of neolithic man.[35]

The third factor, food and its assimilation, is more closely associated with the foregoing than is usually realised. Leonard Hill [36] has shown that sedentary occupations in still warm atmospheres have the effect of lowering the general metabolism and of reducing the desire for food, thus producing a similar effect to actual privation and affecting even the well-paid worker. Acting through long periods during the growing time of life, such factors whenever they arise may stunt growth as well as predispose to illness. McCarrison [37] has indicated that the adult worker and even more the adolescent, need, no less than the growing child, a supply of food rich in vitamines, and balanced in its organic and inorganic

[30] *Memorials of London* (H. T. Riley), p. 339, *et seq.*

[31] W. White, *Phil. Trans.*, lxxii., p. 35.

[32] *D. Erasmi Epistolae*, lib. xxii., epist. 12, London, 1642.

[33] John Simon, *English Sanitary Institutions*, p. 106.

[34] John Howard, *State of the Prisons*, p. 10.

[35] Carnegie United Kingdom Trust. Report on *The Physical Welfare of Mothers and Children*, vol. iii., Scotland. Plates XIII., XIV., and XV.

[36] L. E. Hill, *Medical Research Committee, Special Report Series*, No. 32.

[37] *Medical Research Committee, Special Report Series*, No. 38; also *B. Med. Jour.*, Feb. 21, 1920.

components; without this they lack both vitality and resistance. The foods required, eggs, butter, animal fats and fresh vegetables, are very expensive, but are not replaceable by the cheaper vegetable oils and lard. Many dietaries which appear satisfactory on a mere caloric basis prove failures owing to the lack of these vital elements. The industrial worker is doubly handicapped; he not only loses his appetite and takes scarcely enough to provide the necessary energy for his work, but, too often, he takes even that in the form of margarines and canned foods which do not supply adequate vitamines. There is reason to think that the war-time rationing of foods and control of prices was to the benefit of the growing child of the elementary-school class in that it secured a more equable distribution of the essentials at a rate which was within the range of the family exchequer of a very large number. This helps to explain the undoubted improvement of children's health and physique during a period in which disaster might confidently have been anticipated. If, as is probable, physique suffered with the concentration of the population in the industrial areas, no small part may have been played by the confinement in a relaxing atmosphere and the substitution of inert for live foods. The worker who emigrates to more rural surroundings reverses these conditions and, if young enough, recovers part of his lost physique, and in any case his children, not being handicapped, fulfil their true potentialities. With feeding as with housing, though the industrial age brought its own defects, yet the contemporaneous increase of civilisation provided the remedy for some of the previous evils, such as those arising from imperfect methods of food preservation.

Gilbert White wrote in 1778 [38]: 'Three or four centuries ago before there were any enclosures, sown grasses, field turnips or carrots, or hay, all the cattle which had grown fat in summer and which were not killed for winter use were turned out soon after Michaelmas to shift for themselves through the dead months, so that no fresh meat could be had in winter or spring.' The curing at the best was very imperfect, and the diet of the poorer classes would be the semi-putrid sides of bacon, mutton or beef. Indeed, it was enacted that such should be given to the outcast by the Scottish Parliament at Scone in 1380.[39] 'Gif ony man brings to the market corrupt swine or salmond to be sauld, they sall be taken by the baillie and incontinent without any questions sall be sent to the lepper folke; and gif there be no lepper folke, they sall be destroyed alluterlie.' Such continual winter sufferings must have worked harm, seeing that it was not a matter of an occasional meal but a steady regimen. No wonder an Aberdeen physician wrote of the effects: 'As we see dailie the pure man subject to sic calamitie nor the potent, quha are constrynitt be povertie to eitt evill and corrupte meittis, and diseis is contracit, heir of us callit pandemiall.' [40]

Toward the end of the eighteenth century the long-standing defects of food and housing were in full force, and their influence was accentuated by the coming of industrialism and the massing of people in towns. Thus disease from bad feeding and insanitary surroundings was the bane of

[38] *Natural History of Selborne.* Letter to Barrington, Jan. 1778.
[39] *Acts of Robert III., Regiam Majestatem,* p. 414. Quoted by Creighton, *l.c.*, p. 113.
[40] Gilbert Skene, *Treatise on Plague,* Bannatyne Club ed., p. 6.

the metropolis and of the larger cities. Sir W. Fordyce[41] could write: 'I speak within the bounds of truth when I assert that, judging from the cases brought to my notice since 1750, there must be very near twenty thousand children in London, Westminster and the suburbs ill at this moment with the hectic fever, attended with tun bellies, swelled wrists or ankles or crooked limbs, owing to the impure air they breathe, the improper food on which they live, or the improper manner in which their fond parents bring them up.' Within our own memory disease such as is described by Fordyce has become unknown; rickets in mild form still reduces stature, but severe deformities are rare in London and the South, though as yet to be found, albeit in lessened numbers, in the industrial cities of the North. The evils were checked in part by the various Factory and Public Health Acts and by improved sanitation which gradually came into force, while other causes of malnutrition, such as late hours, lack of sleep, uncleanliness, and premature heavy work, have more recently given way before the force of the higher standard of civilisation and of personal well-being.

Modern medical inspection and treatment are fast counteracting the chief causes depressing the health and physique of the children, and are also dealing with contributory secondary factors, such as defective teeth and other foci of chronic sepsis, verminous conditions and unsuitable clothing. No one who compares photographs of present-day children with their predecessors of the seventies can doubt the change. It is significant that the town is now gaining over the country and that London children are now second to none. The treatment schemes did not come into force until just before the war, and affected almost exclusively children who did not reach military age in time to appear before recruiting boards, so that the benefits of the system could not be brought out in the Report of the Ministry of National Service. In this direction the future seems secure.

There remains the gap between the school and adult life. An experienced Scottish recruiting board reported a falling off during adolescence both in the agricultural and the industrial classes.[42] In the former there are 'the evils of the bothy system, with its lack of home comforts, and the tendency to live on canned food'; in the latter 'the boy goes to the factory at fourteen, by sixteen he is earning full wages, indulging in all kinds of excesses, not having his due share of sleep and living on unwholesome foods.' The young artisan, apprenticed to his trade, has far more favourable conditions; 'he does not realise his full wage-earning capacity so early, his home is better, his social conditions more equable, he has not the same opportunities for excesses and lives a more physiological life.' The general impression of the recruiting reports was that the most critical period in determining the physical standard of manhood was the age from fourteen to eighteen. With any extension of facilities for apprenticeship or trade instruction, with opportunities for the further treatment of ailments, even though these be of a voluntary character, much would be gained. Moreover—since the use made of these facilities would depend

[41] W. Fordyce, *A new Enquiry into the Causes, Symptoms and Cure of Putrid and Inflammatory Fever*, London, 1773, p. 207.

[42] *Report, Ministry of National Service*, vol. i., p. 138.

on the mentality and character of the individual—the youth with the best mind and good will should gain the advantage and be favoured in his prospects of a successful marriage, through which he could transmit these qualities to further generations.

Turning to the genetic aspects of the subject, it is clear that the future of the nation depends on the interaction of two somewhat opposed processes, reproductive and lethal selection. Fecundity is a heritable trait, and parents who themselves are members of large families tend to produce many offspring who, in their turn, are similarly prolific. Lethal selection, on the other hand, counteracts this tendency in that the demands of a large family reduce the chances of the parents protecting themselves or their offspring, since the available care has to be distributed over a larger number. It will be noted that the shorter the intervals between successive births, the higher is the rate of infant and child mortality.

The materials for any investigation into changes in density of population are very scanty until the decennial censuses can be consulted. While there are reasons to think the country was by no means sparsely occupied in early days, there are no, even approximate, estimates until the fourteenth century, when the population of England and Wales is believed to have been about three million. There was a slow rise to six and a half at the middle of the eighteenth century, thence on a growth to nearly nine million at the first census of 1801, sixteen million in 1841, and twenty-six in 1881. After this the rate was retarded, and in 1921 the population was approximately thirty-eight million. The period of rapid growth coincided with the industrial development of the early nineteenth century, the slowing down with the rise of competition from abroad.

It is important to note that the increase of population was not uniformly distributed, either as to district, class, or occupation. In the earlier days the greatest density of population was, in the main, south of the line from the Severn to the Wash but extending up to Lincolnshire and the East Riding, and the predominant occupation was agriculture. A change began with the great development of pasture and the relative abandonment of arable land which reached its height in early Tudor times, when Hythloday could be represented in ' Utopia ' as saying : ' Your shepe that were wont to be so meke and tame and so small eaters, now, as I heare saye, be become so great devowerers and so wylde, that they eate up, and swallow downe the very men themselfes. They consume, destroye and devoure whole fieldes, howses and cities.' [43] This process reduced the numbers, especially in the eastern counties and the southern midlands. Some two centuries later the rise of industrialism in northern areas adjacent to water power and coal led to a great increase of numbers in marshy and moorland districts which had formed the refuge of a scanty and often pre-Nordic population.

The areas of highest fertility to-day are the northern counties and Wales, while the lowest are found south of the line from the Severn to the Wash [44] ; probably the difference is mainly due to social and industrial rather than to racial factors. The rural population is the more fertile ;

[43] Thomas More, *Utopia*, Bohn's ed., bk. i., p. 38.
[44] *Census of England and Wales*, vol. xiii., pt. ii.

even in cities the country-born have larger families than the true urban population. The higher rate of child mortality in the towns increases this difference, so that there is no part of England where the rural areas are not more effectively fertile than the small towns and these than the county boroughs. Their greater numbers, however, ensure that the urban population makes the bigger actual contribution to future generations. The rate of increase of the population is dependent upon the fertility, the age of marriage, the proportion of married individuals and the death rate, especially in early life. Of these there is no reason to suppose fecundity as opposed to fertility has undergone any change, but the other factors have shown marked differences both from time to time and from one social class to another.

Little seems to be known of the age of marriage or the extent to which any class remained celibate in early days; there were certainly restrictions on the marriage of serfs, while in the later mediæval period the craft guilds opposed the marriage of apprentices, and until the nineteenth century subordinates in industries and handicrafts usually lived in and did not marry until they became master men. The less skilled workers soon attain to their maximum earning capacity and marry early, while the office worker and professional man has to wait to establish his position. The agricultural classes and skilled artisans also are noted to marry later than either the unskilled workers, the miners or the factory operatives.

The census of England and Wales for 1911 [45] shows that the highest proportion of married men is to be found among the miners, who are followed at some little distance by the artisans and textile operatives; while the agricultural labourers and the professional classes show the lowest marriage rate of all. The latter figures have a distinctly dysgenic significance which is accentuated by a consideration of the later age of marriage in these classes. Failure to mate is even more marked among the professional women than among the men and has steadily increased decade after decade.

During recent years there has been a decline in fertility, a process which began in the higher classes, who have shown the phenomenon throughout the whole period in which registration data have been available. It is difficult to say what may have been the case in the past, but early genealogies usually record large families though relatively few survivors to maturity, so much so that the population was almost stationary between 1700 and 1750. From the economic standpoint, Pearson,[46] investigating the statistics of various parts of England, has suggested that the fall in the local birth rate became accentuated at certain dates which corresponded with local or general restrictions on the employment of children. Another view would ascribe the decline in fertility to a gradual subordination of the sex instinct with the spread of culture and education. A comparison of the literature of different periods bears witness to a gradual disappearance of the idea that the only career for women was marriage, and that a girl should be reproached as an old maid at twenty. On this basis the decline would have spread from above downwards and would be delayed among certain classes. This factor involves both individual

[45] Vol. xiii., pt. ii.

[46] K. Pearson, *The Scope and Importance to the State of the Science of National Eugenics.*

and group psychology since social traditions and class consciousness as well as personal passion are concerned, which helps to explain the lack of response to the appeals of the enthusiastic eugenist.

That reduction in fertility has been of long standing is strikingly illustrated by Crum's [47] study of the New England genealogies, in which he finds a progressive reduction in the size of the family and an increase in the proportion of childless marriages.

Period	Average size of Family	Percentage of Childless Wives
1750–1799	6·4	1·9
1800–1849	4·9	4·1
1850–1869	3·5	5·9
1870–1879	2·8	8·1

The decline among the professional classes in Britain, even when variations in age and length of marriage are allowed for, is a marked feature of the census of 1911. Of the other classes, miners, agricultural and other labourers have families above the average size, artisans are about the general average, while textile workers and other factory operatives have smaller families. The divergence between the different social classes was less marked in 1850 and reached a maximum in the nineties.

The differential death rate, chiefly due to infant mortality, to some extent modifies the initial differences in fertility; while the high fertility of the agriculturist is largely opposed by the low marriage rate and the relative infertility of the upper classes is exaggerated from the same cause. Both total and effective fertility are affected by female occupation, which tends to restrict the number of births, and also to increase the infant mortality owing to the absence of maternal care for a large part of the day. Such occupations are most common in the case of wives of textile operatives, themselves accustomed to factory and mill life from a relatively early age, and among the wives of the labourers in the towns.

The influence of differences in effective fertility in changing the distribution of the population among different social classes can be seen from a comparison of two tables, the first of which gives the percentage of each social class among the married couples, and the second the percentage of these classes among the surviving children from such parents.[48]

Social Class	Distribution per cent.	
	Couples (Parents)	Surviving Children
Upper and Middle .	10·0	7·2
Distributing . .	16·0	14·1
Skilled Artisan . .	24·6	24·8
Mixed Occupations .	17·0	17·6
Unskilled Labourers .	17·1	18·1
Textile Trades . .	3·1	3·1
Miners . . .	8·7	10·7
Agricultural Labourers .	3·5	4·4
	100·0	100·0

[47] Crum, *Quarterly Journal, American Statistical Association,* 1914.
[48] Census of England and Wales, 1911.

This means, to take a concrete example, that the miners who form only 8·7 per cent. of the parent class provide 10·7 per cent. of the surviving children. The unskilled labourers, the mining and the agricultural classes thus appear to be gaining at the expense of the upper and middle and the distributing classes. Miners and agriculturists are usually of good physique, though from the mental standpoint the change is possibly dysgenic.

There appears to be a general impression that the number of defective individuals, particularly of those suffering from mental defect, is greatly increasing. There is little evidence on this point of a comparable nature, but it may be definitely said that in London no such increase has taken place during the last fifteen years. The stocks from which defective individuals come are certainly often prolific, but the infant mortality is high. Indeed, so far as those individuals who are themselves mentally defective are concerned, the figures from institutions indicate death rates from ten to twenty times as great as those of the normal population. The figures regarding the defectives who have been kept under supervision in their own homes indicate rates far above the normal, though perhaps less than those in the institutions to which the worst cases naturally drift. Contrary also to popular belief mentally defective individuals do not mate in nearly as high a proportion as the normal. Out of some 360 defective girls who, while remaining outside an institution, have been under supervision during the past ten years and who are of reproductive age, only eighteen have married and only seventeen have had illegitimate children, a figure which, if regrettably above zero, is not one to cause alarm. Of their children a large proportion appear up to the present to be of normal capacity. There is some reason for thinking that there is a great intermarriage between defective stocks, and that the actual number of such stocks is in reality quite limited.

The London school service has collected information as to the size of the families one member of which has come to notice on account of mental deficiency. The figure will naturally appear higher than one derived from the census returns, since no knowledge exists concerning childless families of the same stocks or of families in which all the children had died. The figures are corrected to show only completed families which have been taken as those where the mother, at the time of the inquiry, had died or had attained the age of forty-five, and, for purposes of comparison, similar figures are given for the families of children who had obtained scholarships.

Group	No. of Pregnancies of Mother	No. of Deaths	No. of Surviving Children
Imbeciles and Idiots	6·0	1·7	4·3
Children at Schools for the mentally defective	5·3	·9	4·4
Scholarship holders	4·8	·5	4·3

As the differential death rate continues to act there is reason to think that the defective stock are the less effectively fertile by the time the reproductive age is reached. If it be remembered that the factors act still more severely against those themselves actually defective, the reason why the defective has not overrun the country is evident. Experience in any

children's hospital or infant welfare centre reveals the handicap against the children of the mentally inferior parent.

There remains one important factor bearing on physique—namely, emigration. Since the early part of the seventeenth century the British Isles have sent abroad large numbers of the most efficient of their people, agriculturists and skilled workers of all kinds possessed of just the qualities which the nation demands for its own physical good. Where these have come from somewhat isolated areas the result has been a steady loss of the best, with the consequent replacement in the next generation by the offspring of an undue proportion of the next best. This clearly has a dysgenic effect, and it is often stated that this is the cause of the inferior calibre of the inhabitants of some remote hamlets. This—probably the most serious drain to which the nation has been, and still is, exposed—can only be regarded with equanimity on the ground that England's loss is the gain of the daughter nations. The emigrants have been largely of 'Nordic' and 'Prospector' stocks, seeking a wider scope for their energies, and the result will in the end seriously modify the racial composition of some parts of the British Isles, particularly Scotland. So far as there has been any difference between rural and urban areas it is distinctly the former that have supplied the higher proportion of emigrants. Emigration, indeed, in recent years has been a serious factor in rural depopulation.

Summarising the whole survey I would submit that a pessimistic view of the physical or mental condition of the people of England is unnecessary and unfounded. Stature and weight at least are not less than in the days of the 'Making of England,' of Agincourt or of Waterloo. The great war showed the possession of powers of resistance to physical adversity that have never been equalled, and under a test applied to a proportion of the nation never before approached, while the versatility of inventive powers was demonstrated everywhere. So far as the children are concerned, education is more general and the ladder wider and more used than at any period in our history. The general health of the nation is better and the expectation of life longer than ever before. There are no grounds for thinking the physical conditions of any class are worse than that of corresponding classes at previous epochs, even among those persons and classes on whom the adverse conditions of life associated with urbanisation and industrialism have pressed hardest and have been least opposed. The real increase of the unfit is much less than has been assumed from *a priori* arguments. Reproductive selection which has a tendency to increase the apparently less valuable stocks is opposed by a lethal selection which has not been abolished, while emigration from the eugenic standpoint, though a real disadvantage to England, has been a source of strength to the Empire of Associated Nations. The dysgenic tendencies of industrialism are being successfully opposed by the higher level of general culture and the awakening of a national conscience, but more especially by the more intelligent care for the children of the nation, in which the application of preventive medicine to education is playing no mean part. The Education Acts, if they have not revealed every child as a potential university scholar, have proved the best of Public Health measures; while all available evidence points to the intellectual average being equal to that of any other country. Civilisation may be making greater demands

on its bearers, but their qualities are neither diminishing nor deteriorating and more and more are fitted to shoulder the burden.

A younger country in developing its industries can profit by the experience of the older and secure from the start better hygiene and a more effective education, can watch over its most favourable racial elements, establish a public opinion favourable to the early segregation of degenerate types, and, as Canada is doing, can limit immigration to those fit to become citizens of the great Dominion.

Periodical surveys are necessary to check the changes in the population. Failing more extensive measures these may be effected through the records of the medical inspection of school children, though in these anthropometric data are but scanty. Toronto has long been known for its standard survey, and it is to be hoped that similar data will be collected in all parts of the Dominion. The matter is of great importance, since it is only on the basis of careful physical and mental surveys that legislation directed towards social and racial hygiene could properly be introduced and rightly justified. The lack of such information has been a great handicap to the discussion of such measures in Britain, and has allowed a freer play to pessimistic views.

None the less, despite all forebodings, it may confidently be stated that the Mother Nation has remained true to herself and deserves now, as of yore, the encomiums of the 'Polychronicon'[49]: 'Engelond ful of pley, fremen well worthy to pley, fre men, fre tonges, hert fre, fre helth al the leden.'

[49] R. Higden, *Polychronicon*, Trevisa's trans., vol. ii., p. 19.

SECTION I.—PHYSIOLOGY.

PROGRESS AND PROSPECTS IN CHEMOTHERAPY.

ADDRESS BY

H. H. DALE, C.B.E., M.D., F.R.S.,

PRESIDENT OF THE SECTION.

Introductory.

In the mind of every physiologist visiting Toronto to-day one recent advance in our science will certainly be uppermost. We rejoice with our colleagues here in a great achievement which has opened new vistas of knowledge to exploration, has brought relief to unmeasured misery, and has turned the eyes of a world, too often careless of such things, in proper gratitude and well-founded hope to this University and its Medical School. Insulin, and its still marvellous and mysterious action, have held a prominent place in the interest of many of us, myself included, during the past year or two. In one of our meetings, however, we shall have the opportunity of considering the observations and opinions of many who are now working on its properties and their significance, and among them will be some who were associated with its discovery. I have thought it appropriate, therefore, to ask your attention to-day to some recent developments in a widely different field of investigation. The subject which I have chosen presents points of general physiological and biochemical interest, apart from its immediately practical importance for the treatment of disease. It has, further, in one way, a special appropriateness to this year's meeting of the British Association. For our knowledge of an important group of diseases, caused by the parasitic trypanosomes, which have provided the experimental material for a very large proportion of chemotherapeutic investigations, we are in the largest measure indebted to the pioneer work of the distinguished President of the Association, Sir David Bruce.

I. The Theoretical Origin of Chemotherapy.

Chemotherapy may be defined as the specific treatment of infections by artificial remedies. The object of those who study it is to find new remedies which will cure or arrest diseases due to infections, not by alleviating the symptoms or invigorating the patient, but by directly and specifically suppressing the infection. Chemotherapy, in this wide sense, is not entirely of recent growth. When the natives of Peru discovered the value in fevers of the cinchona bark, which the Jesuits brought to Europe in the 17th century, they had found a specific remedy for malaria, which is still the best available. Similarly the natives of Brazil had found in ipecacuanha, which reached Europe shortly after cinchona, a remedy for amœbic dysentery better than any other which our modern systematic

and scientific efforts have produced. Modern Chemistry, indeed, has separated the alkaloids from these drugs, and has made it possible to identify among them the actively therapeutic constituents; Protozoology has revealed the nature of the infections. We know now that cinchona owes its curative action chiefly to quinine and quinidine, and that they act as specific exterminators of the malaria parasites, and not simply as remedies for fevers in general; and we know that ipecacuanha owes its action to emetine and cephæline, and that these act as exterminators of the entamœba causing tropical dysentery, and not simply as symptomatic remedies for dysenteries of any kind. But chemistry has produced no better remedy for malaria than quinine, or for amœbic dysentery than emetine; and the method by which either of these alkaloids cuts short the infection by a particular parasite, the nature of its specific action, remains a fascinating problem.

The modern development of chemotherapy, as a new department in therapeutic science, claiming the co-operation of parasitologists, microbiologists, and synthetic chemists, did not take origin, however, simply from the study of these traditional remedies. It may be regarded rather as an outcome of the study of the natural antibodies. The investigation of these natural antagonists to infection produced a new therapeutic ideal. Not only had they shown themselves to have an intensely specific affinity for the infecting organism of the toxin which caused their production; they were also perfectly harmless to the patient, behaving, in relation to his organism, as normal constituents of his body fluids and tissues. Ehrlich aptly compared them to magic bullets, constrained by a charm to fly straight to their specific objective, and to turn aside from anything else in their path.

Of the artificial remedies, on the other hand, which man had empirically discovered, even of drugs like those just mentioned as being specific for certain infections, the best that could be hoped was that they would eliminate the parasite before they poisoned the patient. And thus, when the limitations of natural immunity were becoming clearer; when it was realised that to certain forms of infection, several of which had proved to be infections by protozoa, the body was unable to produce antibodies of sufficient potency to eliminate the infection and leave the patient immune; the question arose whether, with the new and growing powers afforded by synthetic chemistry, man could not so far rival Nature's achievements as to produce, in the laboratory, substances specifically adapted to unite with and kill the protoplasm of these parasites, as the natural antibodies united with that of others, and to leave the tissues of the patient similarly unaffected. The ideal of this new and systematic Chemotherapy, as the imaginative genius of Paul Ehrlich conceived it, was to be the production by synthesis of substances with a powerful specific affinity for, and a consequent toxic action on, the protoplasm of the parasites, and none for that of the host—of substances, to use Ehrlich's own terminology, which should be maximally parasitotropic and minimally organotropic.

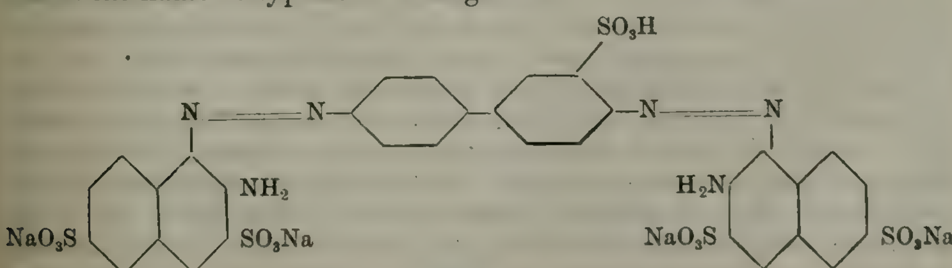
I want to invite your attention to-day to the results which, during the last twenty years, have been produced under the stimulus of this bold conception; not, indeed, to attempt a survey or summary of all that has been done, but, in the light of a few of the suggestive facts which have emerged, to consider how far this hypothesis has justified itself, and whether

it can be accepted as a safe guide to future progress, as it has undoubtedly provided the initiative and working basis for much of what has been accomplished hitherto. Before we deal with some of the actual results obtained, it may be well to consider a little more closely what Ehrlich's working hypothesis involved. The problem was to discover, by chemical synthesis, a compound which, in virtue of its chemical structure, should have a maximal affinity for the protoplasm of a microscopic parasite, such as a trypanosome, and a minimal affinity for that of the host's body cells. These affinities were pictured by Ehrlich, in the terms of his side-chain theory, as determined by certain side-chains of the complex protein molecule, or chemoreceptors, which endowed the protoplasm with specific combining properties. When it is remembered that knowledge of the chemistry of the protoplasm of a trypanosome is almost nil, and that what little we do know suggests that it is very similar to that of our own cells, it will be admitted that the enterprise was one calling for scientific courage and imagination in the highest degree. Complete failure would not have been surprising ; the matter for surprise, and for admiration, is that so large a measure of practical success should, at the end of two decades, already claim record.

II. Trypanosomes and Spirochæts.

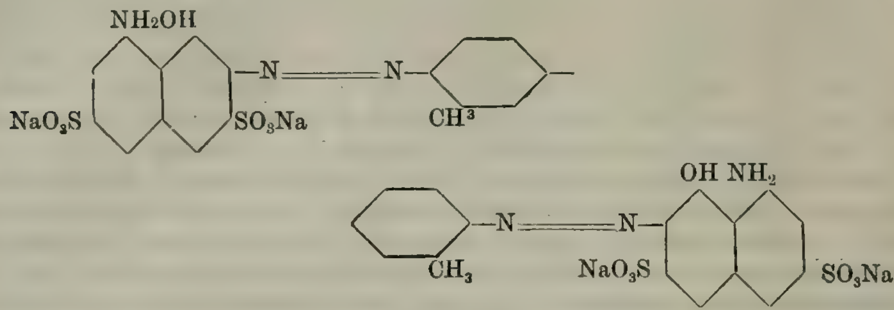
i. The Action of Dyes and Analogous Compounds.

The investigations leading, in the last few years, to a clear promise, at last, of the successful treatment of the diseases in man and animals due to infections with trypanosomes, had at least two different starting-points, the action of dyes and the action of arsenic. Ehrlich's early interest in the synthetic dyes, and his observations of the curiously selective distribution which they often exhibited among the cells and tissues of the body, naturally suggested the possibility of finding, in this group, a substance which would selectively fix itself to the parasite and poison its protoplasm, without injuring that of the host. The technique developed by Laveran and Mesnil, by which a particular strain of trypanosomes could be passed through a series of mice or rats, and produce an infection of standardised type and virulence, enabled the effect of a large selection of dyes to be investigated, with the view of finding one which would favourably influence the infection. A starting-point having been obtained, the resources of synthetic dye production were available to produce an indefinitely long series of derivatives and modifications of the active compound, each to be tested in its turn. In this way Ehrlich and Shiga arrived at a substance which gave experimental promise of curative value, a benzidine dye to which the name ' Trypan red ' was given.



Trypan red.

Two years later, Mesnil and Nicolle, proceeding further along the same path, described an even more favourably active blue toluidine dye, 'Trypan blue.'



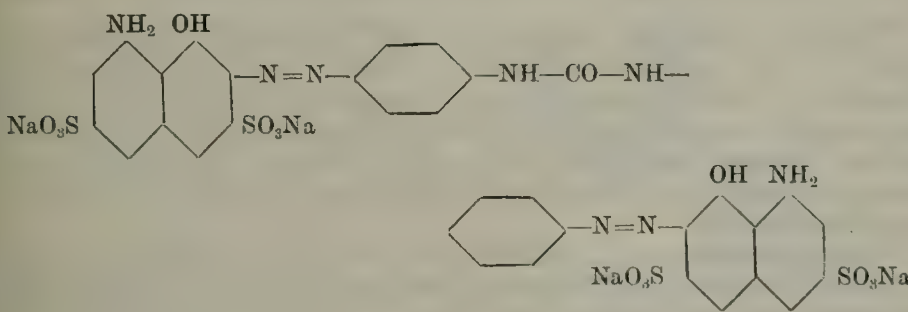
Trypan blue.

This is the only one of the dyes which has hitherto had a genuine practical success in the treatment of a protozoal infection, not indeed by a trypanosome, but by an intracorpuscular parasite of the genus Piroplasma, which infects dogs and cattle. This successful application of Trypan blue to an animal disease has a special interest for us to-day, in that it resulted from the joint labours of last year's President of this Section, Professor Nuttall, with a Canadian collaborator, Dr. Hadwen.

We may turn aside at this point to inquire how far the results even of these earlier investigations corresponded with the theory which gave them their impetus. Did these dyes really act by selectively staining and killing the parasites, and leaving the host's cells untouched? The evidence was certainly not in favour of such a view. Ehrlich and Shiga themselves observed that Trypan red, even in relatively high concentrations, was practically innocuous to the trypanosomes outside the body. The trypanosomes, like other cells, were not stained by the dye until they died, and there was no clear evidence that they died sooner in the Trypan-red solution than in ordinary saline. Again, Trypan red cured an infection by the trypanosome of 'Mal de Caderas' (*T. equinum*) in the mouse, but not the same infection transferred to the guinea-pig, rat, or dog; nor did it cure an infection with the trypanosome of Nagana (*T. brucei*) in mice. Now, to explain such a difference by stating that the affinity of Trypan red for *T. equinum* was much higher than its affinity for the tissues of the mouse, but not than its affinity for those of the rat, would be merely to restate, in terms of the theory, the observed fact that the mouse was cured while the rat was not; and the lack of direct affinity for the dye shown by trypanosomes outside the body made such an interpretation in any case unsatisfactory. One point, however, appeared very significant, and it is met repeatedly in studying the action of effectively chemotherapeutic substances, namely, that the trypanosomes treated with the dye *in vitro*, though neither obviously stained nor visibly harmed, had lost their power of infection, and died out promptly if introduced into the body of a mouse. Under such conditions only minimal traces of the dye are introduced into the animal, and we are left with a series of alternative possibilities. It is possible that sufficient dye has been taken up by the trypanosomes to kill them eventually, the period of survival *in vitro* being inadequate to display its action; or that Trypan red is converted by the

influence of the body fluids and tissues into something which is effectively lethal for the parasite; or, again, that the effect of the drug is not directly to kill the trypanosomes, but, leaving their individual vitality and motility unimpaired, so to modify them that they have lost the power of rapidly reproducing themselves and invading the fluids and tissues of the mouse's body—in other words, have lost that complex of adjustments to the various factors of the host's natural resistance which we crudely summarise as 'virulence.' Such possibilities involve either storage or modification of the dye by the host's tissues, or their essential co-operation in its curative effect.

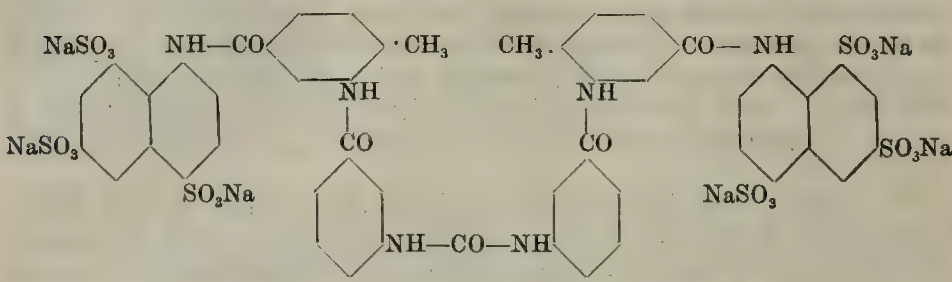
One other active dye must be mentioned as providing the link with a recent, most important advance. Mesnil and Nicolle in 1906 made some promising experiments with a dye, Afridol violet, which differed from any previously tested, in that its central nucleus was diamino-diphenyl-urea.



Afridol violet.

From this time onwards there was no further public indication of progress along these lines until 1920, when Händel and Joetten published the results obtained with a remarkable substance which, as the result of some fifteen years of continuous work by their scientific staff, had been introduced by the great dye and chemical firm of Bayer. This substance, which is not a dye, but the colourless, water-soluble salt of a complex sulphonic acid, has hitherto been known as Bayer '205,' and, for reasons which need not concern us, the firm decided not to publish its formula. To students of their patent specifications, however, it seemed pretty certain that it would prove to be one of a long series of compounds, formed of chains of amino-benzoyl radicles, united by amide linkages, with a central urea linkage, like the dye last mentioned, and terminal naphthylamine sulphonic acid groupings. A number of these substances, having no diazo-linkages, were not dyes, but there was no indication as to which constitution, out of an immense number possible, would prove to be that of the remarkable substance numbered '205.' There is a reasonable probability that its identity has now been settled by the recent work of Fourneau and his co-workers in the Pasteur Institute, who made and investigated an extensive series of compounds of this general type, and found one, which they numbered '309,' which conspicuously excelled all others, even those closely related to it, in the favourable ratio which it displayed, between a just toxic dose and that which caused a trypanosome infection in mice to disappear. As in the case of '205,' the ratio, the 'chemotherapeutic index' of Ehrlich, was found by Fourneau, in some experiments with his compounds, to

be well over 100. At least it may be said that, if M. Fourneau has not identified Bayer '205,' he has discovered another compound having very similar, and probably as valuable, properties.



Fourneau's '309' (possibly identical with Bayer '205').

The most remarkable property of '205' is the long persistence of its effect. A dose injected into a mouse, a rabbit, or a rat will not only free the animal, if already infected, from trypanosomes in a few days, but will also render it resistant to such infection for a period of weeks or even months. During that period its serum, or extracts from certain of its organs, exhibit a curative action if injected into another animal infected with trypanosomes.

Though there seems no reason to doubt that this substance has cured a number of cases of African sleeping-sickness in man, even some in which the disease was well advanced and in which all previously known remedies had failed, the mode of its action still presents a number of attractive obscurities. Like many other remedies which are experimentally efficient when injected into the infected animal, it has little or no obvious action when directly applied to trypanosomes *in vitro*. The paradox is, perhaps, less than usually significant in this case, since the action in the animal is delayed, a period of a few days elapsing before the trypanosomes begin to disappear from the blood. We might suppose that the action is too slow to be recognised during the period of survival of the parasites outside the body, or that it affects not the individual vitality of the trypanosomes, but their power of reproducing themselves. The latter idea is supported, as in other cases, by the fact that trypanosomes treated with the drug *in vitro*, or taken from an injected animal before the curative effect has become manifest, fail to infect another animal. It is contradicted, however, by the observation that the trypanosomes, just before the curative action begins, show not a depression, but a stimulation of reproductive activity, division forms becoming abnormally common. Is it that during or immediately after division the parasites become specially liable to the action of the drug ? It may be so ; but one thing seems perfectly clear, namely, that the action is a very complex one, involving the co-operation, in some way, of the host. For here again it is found that the curative action, on infections by the same strain of trypanosomes, varies enormously with the species infected, a mouse being cured with ease, an ox or a horse with difficulty or not at all. A curious fact is that the rapidly progressive and fatal infections produced in mice by certain pathogenic trypanosomes are easily and certainly cured, while the apparently harmless natural infection, seen in many wild rats, by *T. lewisi* is not affected at all. Then

there are some curious records of treatment in man, in which the symptoms of sleeping-sickness have disappeared, but the trypanosomes are still found in the cerebro-spinal fluid, suggesting that, though the parasites have not been killed, they have lost their virulence and their power of invading the brain substance.

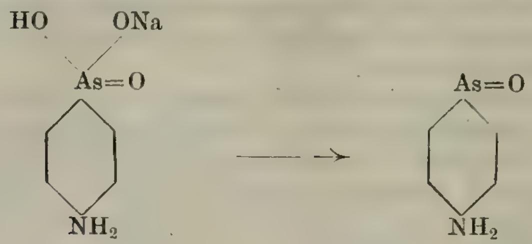
The features of the action of this remedy, however, which have most interest for the physiologist and the biochemist are those related to the long persistence of its effect. '205' has a large molecule, but it is extremely soluble in water, and diffusible through collodion membranes. How, in such circumstances, can we explain the persistence of its sterilising and prophylactic action for months after an injection? At first sight one is tempted to regard it as incredible that a substance with these properties should persist in the body for such a period, and to suggest that the action must be due to its stimulation of the body to form its own protective substances. This possibility, however, seems to be excluded by the fact that the serum of the protected animal does not lose its curative properties if heated. On the other hand, there have recently appeared, some of them only in preliminary abstract, a series of highly suggestive observations, indicating that '205' has properties of entering into a combination of some kind with the serum proteins. After standing for an hour or two in serum, '205' no longer passes into an ultra-filtrate through collodion, and if the proteins are coagulated by heat is not to be found in the filtrate. The proteins of the blood, moreover, are stated to lose many of their characteristic properties by entering into this combination, the blood losing its normal power of clotting, and the serum proteins not being precipitated by mercury salts or tannin.

It would be both useless and presumptuous for a mere onlooker to speculate in detail on the significance, for the curative action of '205,' of properties which are only now beginning to be investigated. One conclusion, however, I think we are entitled to draw. It is sufficiently evident that here is no question of a substance curing simply on account of its affinity for parasites and lack of affinity for the host's tissues. What direct action on the parasite '205' itself may possess has still to be demonstrated; we may feel reasonably certain, on the other hand, that its affinities for the constituents of the host's blood and tissues play an important part in its remarkable and peculiar curative properties.

ii. Derivatives of Arsenic.

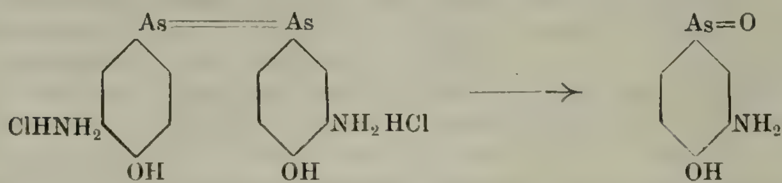
In the case of the other series of investigations which I mentioned, that dealing with the organic derivatives of arsenic, we find again many difficulties, in the way of the simple theory, of a cure due to distribution by chemical affinities. None of the compounds of this series, which have reached practical trial and success in the treatment of spirochætal or trypanosomal infections, atoxyl, salvarsan, or tryparsamide, has a directly lethal action on the parasites in dilutions at all comparable to those which can be safely and effectively produced in the body of the host. The paradox of this direct inertness of atoxyl, the starting-point of the series, seemed to be explained when Ehrlich showed that its reduction to the corresponding arsenoxide produced a substance with an intense

directly lethal action on trypanosomes. Similarly the partial oxidation of salvarsan, to the corresponding arsenoxide, produced a substance having



'Atoxyl.' Arsenoxide from 'Atoxyl.'

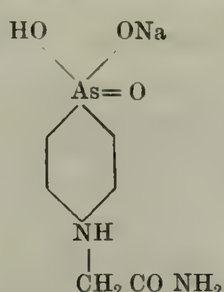
the intensely lethal action on spirochæts or trypanosomes *in vitro*, which salvarsan itself conspicuously and paradoxically lacked. In these cases, we may make the supposition, which Voegtlin and his co-workers, especially, have recently supported by detailed evidence, that the reduction or



'Salvarsan.' Arsenoxide from 'Salvarsan.'

oxidation effected by contact with the tissues is the essential preliminary to the curative action ; a supposition which, it will be noted, again introduces the host as an essential participant in the cure. The fact, that the administration of these relatively inactive predecessors is therapeutically more effective than the injection of the directly active oxides derived from them, would then be explained on the assumption that the slow liberation of these latter in the body, at a rate which never produces a high concentration, provides the optimum condition for their persistent action on the parasites, without danger to the host. This slow and persistent liberation of the directly active substance would be favoured by the physical properties of salvarsan, which at the reaction of the body is practically insoluble, and must be rapidly deposited after injection.

In their recent work on the action of Tryparsamide, the compound,



Tryparsamide.

prepared by Jacobs and Heidelberger at the Rockefeller Institute, which has shared with Bayer ' 205 ' the credit of making the eventual conquest

of African sleeping-sickness a hopeful possibility, Brown and Pearce find it necessary to introduce yet other considerations to explain its effects. Tested by Ehrlich's therapeutic index—the ratio between the lowest curative and the highest non-toxic dose—it gives a relatively unfavourable figure. Brown and Pearce practically abandon the attempt to account for its action on the supposition that it directly kills the parasites, and attribute its value largely to its power of penetrating easily into the tissues and reinforcing there the processes of natural resistance.

iii. Action of Bismuth.

Another conception of the mode of action of these arsenical remedies, also involving a direct participation in the host's tissues, was put forward by Levaditi. He found that from atoxyl a directly parasiticidal preparation could be obtained, by incubating it with an emulsion of fresh liver substance. As the first step, therefore, in the curative action of atoxyl, he postulated a combination of its reduction product with some constituent of the liver or other tissue, giving rise to the essential curative complex, which he named 'trypanotoxyl.' Levaditi's observations were explained by Ehrlich and Roehl as due simply to the reducing action of the liver substance on atoxyl; but it would be difficult to apply this explanation to the quite recently published observations by Levaditi and his colleagues, on the mode of action of bismuth in curing spirochætal infections. A sodium potassium bismuthyl tartrate—a bismuth analogue of tartar emetic—had been found to have valuable curative properties in syphilis and other spirochætal infections. Later, various other bismuth salts, bismuth suboxide, and even finely divided metallic bismuth, were found to produce similar effects. According to Levaditi and Nicolau, these preparations have, by themselves, a relatively weak action, or none at all, on the spirochæts outside the body. If they are mixed, however, with a cell-free extract of liver, which is itself harmless to spirochæts, the mixture, after incubation, acquires a potent spirochæticidal action. The possibility of a mere reducing action of the liver extract seems here to be excluded, since bismuthous oxide, or metallic bismuth itself, yields a spirochæticidal mixture, containing Levaditi's hypothetical 'bismoxyl,' when incubated with the liver extract. If these observations are confirmed, there will be a strong indication that some cell-constituent enters into the composition of, or is essential to the formation of, the directly active substance from any of the derivatives of arsenic, antimony, or bismuth, as a preliminary to its action on an infection due to a trypanosome or a spirochæt. Again we have evidence of an organotropic property of the remedy, as an essential condition of its activity.

iv. Resistant Strains of Trypanosomes.

In the phenomena of the acquisition of resistance, by a strain of infecting trypanosomes to a particular curative drug, discovered and largely worked out in Ehrlich's laboratory, we meet again with facts which can only with the greatest difficulty be reconciled with the assumption that the drug directly attacks the parasites. It was found, for example, that if a mouse infected with trypanosomes received an incompletely effective series of doses of atoxyl, the trypanosomes appearing in the blood at each relapse were more and more resistant to the drug, until they could not

be caused to disappear by any dose of atoxyl which the mouse would tolerate. The strain, having once acquired this resistance, would retain it, on passage through an indefinitely long series of mice, without further treatment. Mesnil and Brimont, however, made the remarkable observation that, if the strain of trypanosomes was transferred to a rat, it immediately became in that animal susceptible again to treatment with atoxyl, remained so as long as it was kept in rats, to reacquire its old resistance to atoxyl as soon as it was re-transferred to mice. Such a fact seems to be not at all explicable on the theory that the directly active agent, to which the trypanosome becomes resistant, is a mere reduction product of atoxyl; it is much more easily reconciled with a mechanism such as that described by Levaditi, in which a constituent of the host's tissues enters into the formation of the trypanocidal substance. We can imagine the trypanosome becoming immune to Levaditi's mouse-trypanotoxyl, and remaining susceptible to the corresponding rat-product.

The whole question of this acquired resistance of the parasites to the action of curative drugs bristles with points of difficulty and interest. Ehrlich attributed the sensitiveness of the parasite, for a particular curative agent, to the possession by its protoplasmic molecule of a special form of side chain, or 'chemoreceptor,' which determined its affinity for that agent. When the trypanosome became resistant, it was simple to suppose that it did so by losing the appropriate chemoreceptors; an atoxyl-resistant trypanosome, for example, had lost its atoxyl receptors. Apart from the objections already mentioned, this conception met a new difficulty, when in Ehrlich's laboratory it was found that the resistance was by no means as rigidly specific as it had first appeared to be. Not only imperfect treatment with atoxyl, but treatment with a particular group of dyes, having no kind of chemical relation to it, was found to produce a race of trypanosomes resistant to atoxyl and to other arsenical derivatives. To suggest that the chemoreceptors for arsenic and for these dyes are identical is merely to restate the fact of this reciprocal action in terms having no definite meaning. Obviously no more precise conception as to its significance can be formed until we know something more of the conditions on which resistance and susceptibility depend. A recent suggestion by Voegtlin has interest in making, at least, an attempt at interpretation in more definite biochemical terms. Voegtlin and his co-workers point out that arsenious oxide and its derivatives readily combine with substances containing a sulphydrile grouping, and find that the toxic action of the organic arsenoxides, on trypanosome and mammal alike, is depressed by the simultaneous injection of excess of various sulphydrile compounds.

$$\mathrm{R{\cdot}As=O} + \frac{\mathrm{HS{\cdot}R}}{\mathrm{HS{\cdot}R}} = \mathrm{R{\cdot}As}\begin{cases}\mathrm{S{\cdot}R}\\ \mathrm{S{\cdot}R}\end{cases} + \mathrm{H_2O}.$$

III. Suggested Reaction of an Arsenoxide with a Sulphydrile Compound.

The work of Hopkins, showing the importance of one such sulphydrile compound, reduced glutathione, in the hydrolytic oxidation-reduction processes of the cell, suggests to Voegtlin that a combination with such groups, and consequent suppression of this vital function, may explain

the toxic and curative actions of the arsenical derivatives, and that a formation by the trypanosome of the sulphydrile compound, in excess of its vital need, may be the basis of acquired resistance. If certain dyes similarly affect this cellular oxidation system, the production under their influence of strains of trypanosomes resistant to arsenic would also be explained. So stated the suggestion leaves many aspects of the problem still unconsidered; but it may at least be allowed the merit of an attempt to interpret the action of these drugs in terms of known biochemical facts.

IV. Emetine and Dysentery.

To turn to another example of a chemotherapeutic problem, I may mention briefly some results obtained, some years ago, by Mr. Clifford Dobell and myself, in an attempt to explore the curative action of emetine and the other alkaloids of ipecacuanha in amœbic dysentery, with a view to finding a more effective treatment. At the time when we took up the problem it seemed simple. Rogers had recorded that the amœbæ obtained from a case of amœbic dysentery, and treated *in vitro* with emetine, were rapidly killed by the alkaloid in dilutions as high as one part in 100,000. This seemed to explain the action of emetine as a simple and direct one on the parasites, and to provide a rapid method for testing a series of compounds for their therapeutic possibilities. We failed, however, as other observers before and since have done, to confirm the observation ; on the contrary, we found that the dysenteric amœbæ, obtained from cats secondarily infected, or, in a control observation, directly from man, were surprisingly insusceptible to the action of emetine, living for hours in concentrations much greater than the highest which they would tolerate of other alkaloids, which had no curative action in dysentery. One of the other natural alkaloids of ipecacuanha, methyl-psychotrine, and certain artificial derivatives of emetine, were much more effective in killing the amœbæ in the test tube, and at the same time were practically devoid of the characteristic toxicity of emetine and cephæline for mammals and for man. Here, on the classical assumption of chemotherapy, should have been ideal remedies for amœbic infection—substances much more parasitotropic and much less organotropic than those already known to be effective. Yet each of them in turn, when administered to patients suffering from amœbic dysentery, in doses much larger than those in which emetine could be tolerated, produced no effect whatever on the dysentery, which promptly cleared up when emetine was subsequently given. Among the members of this group of alkaloids which were tried, the curative effect seemed to be proportional rather to their toxic and nauseating action on the patient, than to their lethal action on the isolated amœbæ. Yet emetine and cephæline are not mere symptomatic remedies ; they definitely stop the progress of infection by the amœbæ, and, properly administered, eliminate them altogether from the body.

Yet another puzzling observation, made by Dobell and myself, was that an amœbic infection which readily yielded to treatment with emetine in man, was entirely uninfluenced by emetine when transferred to the cat. In no way is it possible to account for these facts without admitting a co-operation of the patient's tissues in the curative action ; nor, with that admission, can we do more than consider possibilities. We only know that

the truly parasitic *Entamœba histolytica*, which cannot live without invading the tissues, can be checked in this invasion and eliminated from the body by administering emetine, while other Entamœbæ, which live on fæcal debris, remain unharmed. Whether the tissues are so altered that the amœbæ cannot invade them, or the amœbæ, without being directly killed, are so weakened in virulence that they cannot invade the tissue and obtain their food, but succumb in face of the normal resisting powers of the host, are possibilities on which we can only speculate, and no method of bringing them to the test of experiment has yet been found.

The work of Morgenroth and his co-workers, extending now over more than a decade, has again led them to emphasise, in connection with the curative action of substances which they have examined, a fixation to the cells and tissues of the host, a definitely organotropic property, as an important factor in the effect. Two examples may be mentioned.

V. Quinine and Malaria.

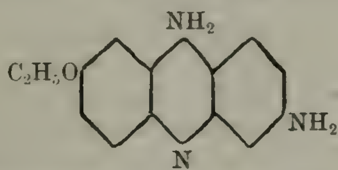
One of the earliest of chemotherapeutic discoveries, that of the cure of malaria by quinine, had never been satisfactorily explained. There was no evidence establishing even a probability that quinine, in such concentrations as can be tolerated in the blood of the living subject, would directly kill the malarial plasmodia, especially if these were partly screened from its action by their position in the interior of the red corpuscles. Morgenroth, from the results of his determinations by biological methods of the distribution of quinine in blood, is led to the conception of quinine as acting on malaria, in virtue of its fixation by the red corpuscles, either killing the trophozoites in their interior, or blocking the entry into them of the merozoites of the asexual cycle. On this latter supposition, it will be seen that quinine would act, not by killing the malarial parasites, but by rendering the blood unfitted for their multiplication. They are supposed to fall a prey to the natural defensive substances in the plasma, because a film of quinine denies them access to the red corpuscles, in the interior of which they could continue their development in safety. There are discrepancies between Morgenroth's determinations of the distribution of quinine in favour of the red corpuscles, and those obtained by direct chemical means, which would still need to be reconciled before either theory of the curative process in malaria could be fully accepted. Meanwhile, these suggestions are of interest as another example of the need found, more and more, by workers in this field to regard an organotropic property of a drug not as detrimental to its curative action but as an essential factor in the chemotherapeutic process.

VI. Remedies for Bacterial Infections.

This same property, of fixing themselves to the red blood corpuscles or to the connective tissue, has been observed by Morgenroth and his co-workers with the higher homologues of quinine, ethylhydrocupreine (' optochin ') and octylhydrocupreine (' vuzin '), and with the dyes of the acridine series, with which they have obtained promising results in the treatment of bacterial infections. In the treatment of pneumococcus infections by optochin several factors, other than those of immediately

lethal action of the alkaloid on the pneumococci, appear to be concerned. Evidence was obtained by Moore, for example, which suggested that the defensive reaction of the host was an essential factor in the cure, optochin, in doses inadequate to kill the pneumococci, rendering them liable to the action of specific antibodies; and some experiments of Felton and Dougherty suggest that an excessive dose of an alkaloid of this class, by suppressing the natural defensive reaction, may even allow the fatal spread of an infection which a lower dose would cure. Morgenroth, on the other hand, emphasises the part played by the organotropic properties of optochin and vuzin, in enabling the red corpuscles to act as carriers of the drug to the point of action, and the connective tissues to form local depots of it.

An acridine dye, named Trypaflavin, was under study in Ehrlich's laboratory in 1914 as a trypanocidal remedy, and was found during the war, by Browning and his co-workers, to have valuable properties as an antiseptic for infected wounds and mucous membranes, for which, under the name 'Acriflavine,' it is still used. Since the war, other dyes of this series have been investigated by Morgenroth and his school, and one of them, called 'Rivanol,' is stated to be particularly effective as a tissue antiseptic, especially in conditions of spreading infection due to streptococci.



'Rivanol' (2-ethoxy 6, 9 diamino acridine).

In the case of 'Rivanol' also, evidence has been brought forward that it is fixed by the red corpuscles and the subcutaneous tissues, protected thereby from excretion, or held at the point where its curative action is required. From these body cells it is suggested that the dye is gradually given up to the cocci, on which its action is exerted, by a process called 'transgression' by Morgenroth. This is a process by which a substance is passed from one medium to another, when both have strong affinities for it, through a layer of an intervening medium for which it has no affinity, and in which it may be almost insoluble. In this process of depot formation, and gradual liberation of the active substance, we are concerned with a phenomenon which certainly has a widespread importance for chemotherapeutic action. We have earlier seen evidence of such fixation and gradual release in the cases of Bayer '205' and Salvarsan.

Another suggestive feature of the action of 'Rivanol' on streptococcal infections, is that such organisms as escape the immediately lethal effect of the dye appear to have lost their hæmolytic properties, and to have been modified into a relatively avirulant strain.

VII. Conclusion.

We have considered but a few examples of the directions in which chemotherapeutic investigation has proved practically fruitful, including some in which it shows, at the moment, the most hopeful signs of progress. If one considers any one group of investigations by itself, one may easily feel, at the same time, elated by the practical success obtained, in the cure of some infection which, but a few years ago, seemed beyond the reach of treatment, and depressed by the disharmony between the results of experiment and the theoretical conceptions, hitherto available, of the nature of the chemotherapeutic process. Some of the most notable practical triumphs in this field have resulted, not from experimental investigations based on theory, but from an almost empirical trial, on human patients suffering from one type of infection, of a remedy which had experimentally shown promising results in infections of a different, and sometimes of a widely different, type. The partial success of tartar emetic in trypanosome infections might have justified a hope that it would have some effect in kala-azar, but hardly a prediction of its really remarkable efficacy in that previously intractable form of infection. Still less would it have justified expectation of the brillant success of this same drug in infections by the Schistosoma or Bilharzia-worm, which but recently seemed almost beyond the hope of any kind of treatment. With such instances in mind, one might, but a year or two ago, have been tempted to suggest that the attempts at theoretical investigation, of the intimate mechanism of the chemotherapeutic process, had contributed little to the practical achievements, and that a reasonably intelligent empiricism was still the safest guide. I do not think that the suggestion would even then have been defensible, and it would assuredly have been stultified by the results of the past few years. Patient, systematic exploration, by routes of which the initial sections were already mapped in the early days of chemotherapy, has in these recent years again led to results of major importance, both for practical therapeutics and for the theoretical basis of future advance. That the original theoretical framework begins to show itself inadequate for the expanding fabric is good reason for its reconstruction ; but we may well beware of hasty and wholesale rejection, remembering that it served the early builders well. I think that it is especially encouraging to note that, though, in the action of almost every remedy which has proved its value in the specific cure of infection, there are features which cannot be interpreted by a strict application of Ehrlich's distribution hypothesis, the discrepancies begin to show a new congruity among themselves. Repeatedly we find phenomena which point to the need of modifying the theoretical structure in the same direction. The conception of a remedy not killing the parasites immediately, but modifying their virulence, or lowering their resistance to the body's natural defences; of a remedy not acting as such, but in virtue of the formation from it in the body of some directly toxic product, either by a modification of its structure or by its union with some tissue constituent ; of an affinity of the remedy for certain cells of the host's body, leading to the formation of a depot from which, in long persistent, never dangerous concentration, the curative substance is slowly released ; all these conceptions present themselves, again and again, as necessary for our

present rationalisation of the effects observed. It can hardly be doubted that they will potently influence the methods by which, in the immediate future, new and still better specific remedies are sought. But though our practical aim, in relation to the affinities of a remedy for the parasite and for the host's tissues, may be radically changed, the meaning of these specific affinities, so delicately adjusted to a precise molecular pattern, remains dark. Ehrlich's chemoreceptors may no longer satisfy us, but we have nothing equally definite to replace them. I have endeavoured to indicate what seem to me hopeful signs of new contacts between biochemistry and chemotherapy. There is promise, in another direction, that at least some aspects of the problem of immune specificity are being brought within the scope of strictly chemical investigation, as in the recent work of Avery and Heidelberger, on the constituent of a pneumococcus which combines with the specific precipitin. As in Ehrlich's pioneer work in chemotherapy, it can hardly be doubted that an increased understanding of the meaning of immune specificity, which but a short while ago might have seemed hopelessly beyond the range of attack by chemical weapons, will still influence ideas, and help to shape the course of further investigations, on the chemotherapeutic process. As the biological complexity of the problem is realised, it becomes increasingly a matter for wonder and admiration that so much of practical value has already been achieved —the treatment of the spirochætal infections, syphilis, yaws and relapsing fever, revolutionised; Leishmania infections, kala-azar and Baghdad boil, and Bilharzia infections, which crippled the health of whole populations in countries such as Egypt, now made definitely curable; trypanosome infections, such as the deadly African sleeping-sickness, after years of alternating promise and disappointment, brought now at last within the range of effective treatment. And if such results have already been attained, in a period during which practice has often and inevitably outrun theory, we may well be hopeful for a future in which fuller understanding should make for more orderly progress.

SECTION J.—PSYCHOLOGY.

PURPOSIVE STRIVING AS A FUNDAMENTAL CATEGORY OF PSYCHOLOGY.

ADDRESS BY

PROFESSOR WILLIAM McDOUGALL, F.R.S.,

PRESIDENT OF THE SECTION.

We who are workers in the various fields of Psychology are happy in the knowledge that our science is rapidly developing, extending its influence into every sphere of human activity. The institution and the success of this Section of the British Association are good evidence that our colleagues in the other branches of natural science have recognised the claim of Psychology to take its place among those other branches. And, though in Great Britain there are still all too few Chairs of Psychology, in Canada and America the Universities and Colleges are now providing abundant opportunities for teachers, students, and research workers, opportunities that are being eagerly and fully used.

Yet, in spite of this happy state of affairs, there is manifested among us psychologists a certain uneasiness as to the status of our science, an anxiety lest the psychologist be regarded as not quite really and truly a man of science. This anxiety is, I think, exerting an unfortunate influence on the development of our science, an influence which shows itself in two principal directions.

On the one hand is a group of psychologists who, actuated by the desire to mark off an exclusive field of study as their province, define psychology as the science of consciousness and would confine themselves to the analytic description of conscious states as complex conjunctions of elements or units of some kind. On the other hand are those who, feeling that such analytic description, whether it resolves consciousness into a complex of sensations or atoms of consciousness, or into larger more complex units (the so-called configurations or *Gestalten*), brings but little light on human nature and conduct, and can hardly claim to be in itself a science, are driven to the opposite extreme; they ignore this realm of facts, alleged to be the peculiar and distinctive field of psychology, and they would bring to the study of man only those methods of observation, description, and explanation which are used in the physical sciences. These two tendencies, which, when they are carried to extremes, result respectively in what is unfortunately called 'structural psychology' and in 'behaviorism,' although so different in their outcome, are but two expressions of one desire, the desire to make psychology conform to some preconceived notion of what a science is or should be. The 'structuralist'

aims at marking out a peculiar and exclusive field of objects of study. The 'behaviorist' slavishly accepts the physical sciences as his model, and seeks safety from the charge of being unscientific by confining himself to the use of the methods of observation, description, and explanation current in those sciences.

Although a very considerable number of psychologists are following these two widely divergent lines (especially, perhaps, in America), I may, I think, take it for granted that to the majority of us neither line is satisfactory. We feel that both are the expression of a lack of courage; of an undue timidity. In face of the imposing edifice of the physical sciences, the one party shrinks back and seeks to define a little field of knowledge altogether peculiar to itself, within which the psychologist can disport himself at his own sweet will without fear of collision or conflict with the other sciences; the other party seeks safety by taking cover in the bosom of the herd, carefully avoiding all speech or action that might, by marking him as a distinctive variety of the species scientist, bring upon him the suspicious glances of other members of the herd.

There is yet a third large group of psychologists who, moved by the same desire as these others, yet seeing that neither group achieves, nor can hope to achieve, a satisfactory science of human nature and conduct, seek to escape from the limitations of both groups by combining the procedures and the conclusions of both. These adopt the analytic description of consciousness (whether of the 'sensationists' or the 'configurationists') and they accept the mechanistic explanation of conduct of the 'behaviorists'; and they seek (by the aid of the principle of psychophysical parallelism or of epiphenomenalism) to put the two together in parallel columns, to form what can only be called a lame apology for a science.

The very fact that this undue timidity has produced these two widely divergent and aberrant (not to say abortive) types of psychology is its sufficient condemnation. We should take warning from it; we should be led by it to see that a policy of courage is also the policy of safety. I urge that we psychologists are now numerous enough and strong enough to stand together, to form our own herd, a herd in which our more timid members may find the shelter which they crave. In other words, I urge that the time has come when the students of human nature should boldly claim autonomy, or, at any rate, dominion-status, for their science; they should invoke and boldly apply the principle of self-determination.

I urge that this policy of safety through boldness is justified and demanded at the present time by considerations of three kinds, in addition to the fact of the unsatisfactory results of the policy of timidity which I have already indicated.

First, psychology has now at its command an immense mass of data, facts of introspective observation and facts of behaviour, demanding to be synthesised in our science, not merely to be placed side by side in parallel columns.

Secondly, psychology has found many important fields of application, in education, in medicine, in industry, in the social sciences; and all these require a psychology, a science of human nature, very different from the mere description of consciousness and from the mechanistic explanation of behaviour, and different also from the parallel-column psychology.

Thirdly, the policy of boldness is abundantly justified by the present state of the other natural sciences.

I propose to dwell briefly upon each of the three classes of consideration in turn. And in relation to each I desire to urge that the most fundamental need of psychology, the first demand to be met by the policy of boldness, is the adoption without reserve of the conception of purposive striving as valid, useful, nay, indispensable, and therefore true.

The life of man from birth to death is one long series of purposive strivings. Sometimes, as when he plans his career and sets out to build up a home and a family, his goal is remote and somewhat vague, defined in his mind in general terms only ; sometimes it is precisely and exactly defined, as when he goes to eat his favourite dinner at his favourite table in his club ; sometimes it is near and yet but vaguely defined, as when, with open mouth and feeble movements of head and trunk, he seeks the nipple of his mother's breast ; or when, during an absorbing after-dinner conversation, he reaches out to put a piece of candy in his mouth. There is a vast range of differences in respect of the nearness or remoteness of the goal ; and in respect also of the clearness, fullness, and adequacy with which he thinks of his goal. And there is also a wide range of differences between his successive strivings in a third respect, namely, in respect of the urgency, the intensity, the concentration and output of energy manifested in his striving at any movement. Yet, in spite of these wide differences, the striving is always one aspect of his waking life. And even in his dreams, as we now realise, thanks to Professor Freud, the striving goes on, bringing what strange and partial satisfactions it may to the buried, thwarted and denied tendencies of his nature. From top to bottom of this scale of strivings we have to do with the same fundamental phenomenon. In the instances near the top, the more developed modes of mental life, involving the solving of a defined problem, the thinking out of a plan, we all recognise the purposive nature of the striving. The goal, as envisaged, governs the movements of both mind and body.

In instances at the lower end of the scale, introspection, or rather retrospection, inevitably fails to seize and report the thinking of the goal as distinct from the perceiving of the situation of the moment. Yet the continuity of the series justifies us in regarding its lower members as fundamentally of the same nature as its upper members, and in applying the term ' purposive ' to them all alike.

Even in laboratory experiment, where the conditions are commonly so set as to reduce the striving factor to a dead level of uniformity and monotony, it refuses to be ignored for ever ; and so, after a generation of experimentation that ignored it, it is rediscovered and reinstalled in its place of fundamental importance, disguised under some such terminology as ' determining tendency,' or ' motor set,' or ' conditioned reflex,' or ' prepotent reflex,' or what not.

Under all three of the types of psychology we have noticed, this most vital, essential, distinctive aspect of human life escapes the psychologist. For it cannot be described as either a sensation or a configuration (*Gestalt*). And it is not to be discerned by an inspection of the detailed movements of the limbs or of other bodily organs, no matter how exact.

Nor can it be restored or recovered in the psychology of parallel columns. It can be discerned in others only by sympathetic observation and inter-

pretation of the course of their lives. If, under the influence of any metaphysical dogma or any supposed rule of method, you overlook it from the start, you cannot introduce it into your otherwise completed picture of human nature, as an element to be added to and put alongside others already described.

It is too all-pervasive for such treatment. As well might the landscape artist, after painting a picture without atmosphere, attempt to add it by drawing a smear of paint across the whole. This is the difficulty found by students who have been brought up on the parallel-column psychology, as I know from instances of such students who have found difficulty with my frankly purposive 'Outline of Psychology'; nor are such students helped to a truer view of human nature by those books on psychology which, after describing man after one or other of the three fashions we have noted, throw in perfunctorily as an afterthought a chapter on 'The Will.' If striving has been ignored throughout the composition, 'The Will' cannot be added to the picture as a finishing touch. Having learnt to look upon man as a bundle of mechanical reflexes, a superior penny-in-the-slot machine, whose workings are mysteriously accompanied by various 'elements of consciousness,' they can find no place in their completed picture for yet another element called 'a purpose'; it refuses to fit in among the other blocks; there is no room for it, and, as they think, no need for it; and it seems to them quite an ambiguous, not to say shady and suspicious, character; at best it appears to them as a disturbing intruder.

But let the budding psychologist ponder some phase of human life that is dominated by some strong but thwarted desire. Let him consider the strange yet familiar case of Romeo seeking the Juliet who is forbidden to him. How this desire to see, to hear, to touch the loved one dominates his life, waking and sleeping! How it fevers his blood; wears him to a shadow; keeps him running to and fro, scheming, trying, hoping, desponding, exulting, despairing, and always desiring! The desire governs all his thinking and acting; the most rooted habits and mental associations are as nothing in the course of this torrent of purposive activity, all directed to Nature's most imperative goal.

Can we accept any account, any description or explanation of human life, which leaves out of the picture this all-important aspect that we call impulse, desire, striving towards a goal?

When we turn to the fields of applied psychology, the same truth stares us in the face. In every field we find that the most urgent practical problems are concerned with the striving aspect of human nature. The most fundamental task of the educator is to awaken an interest in and a desire for knowledge and self-development. The psychiatrist must study and redirect if possible the conflicting desires of his patient, his subconscious as well as his conscious motives and impulses.

The personnel manager is chiefly concerned with incentives, rewards, jealousies, rivalries, discontents, loyalties, ambitions, and aspirations. The lawyer, the judge, and the jurymen are primarily concerned to determine motives, intentions, and responsibility. The politician, the economist, and the moralist are, or should be, primarily concerned with relative values and the means to make real or actual the highest values of mankind, by harmonising and co-ordinating the conflicting motives of our social life.

In all these cases a psychology that ignores the all-pervading purposiveness of human life is of no use; for, if it is consistent, important words that are essential to the intelligent discussion of human affairs (such words as motive, intention, desire, will, responsibility, aspiration, ideal, striving, effort, interest) are of no meaning for it; or, if they are used, are used with a meaning so thin and so different from that of ordinary discourse, that profitable converse with the practical man is impossible.

I leave that large topic with these few words and pass to my third consideration in support of the policy of boldness. Thirty to forty years ago, when I began to study science, considerable moral courage would have been required to insist upon the purposive nature of man. For at that time the great wave of scientific materialism was still but little past its climax. It was the day of Spencer and Huxley, of Clifford and Tyndal, of Lange and Weismann, of Verworn and Bain. The world and all the living things in it were presented to us with so much prestige and confidence, as one vast system of mechanistic determination, that one seemed to be placed before two acutely opposed alternatives: on the one hand, science and universal mechanism; on the other hand, humanism, religion, mysticism and superstition.

But to-day how different is the situation! Even at the date I speak of, a few great physicists warned us against regarding the principles of physical science as adequate to the interpretation of human life. And to-day those few voices have swelled to a chorus which even the deafest biologist can hardly ignore. Einstein and Eddington and Soddy and a score of others repeat the warnings of Maxwell and Kelvin and Poynting and Rayleigh. And the physical universe of eternal hard atoms and universal elastic ether, the realm of pure mechanics, has become a welter of entities and activities which change and develop and disappear like the figures of the kaleidoscope. The psychologist who would believe in the efficiency of human effort no longer needs to fling himself in vain against the problem—How can Mind deflect an atom from its predetermined course? For the atoms are gone; matter has resolved itself into energy; and what energy is no man can tell, beyond saying—It is the possibility of change, of further evolution.

In physiology the mechanistic confidence of the nineteenth century is fading away, as the complexity of the living organism is more fully realised, as its powers of compensation, self-regulation, reproduction and repair are more fully explored.

In general biology the mechanistic Neo-Darwinism is bankrupt before the problems of evolution, the origin of variations and mutations, the differentiation and specialisation of instincts, the increasing rôle of intelligent adaptation, the predominance of mind in the later stages of the evolutionary process, the indications of purposive striving at even the lowest levels, the combination of marvellous persistency of type with indefinite plasticity which pervades the realm of life and which finds its only analogue in the steadfast purposive adaptive striving of a resolute personality.

All these considerations, I say, should encourage us to claim autonomy for psychology, the right to choose, shape, and refine its own fundamental conceptions. We should now easily find the courage to be anthropomorphic in describing man. Instead of accepting the abstract conceptions of physical science and attempting to build up from them a plausible

mechanical dummy which shall stand for man in our science, let us frankly acknowledge that man is that thing in all the world with which we have the most intimate acquaintance. Let us begin by accepting him for what he seems to be, a thinking being that strives to attain the goals he desires, to realise his ideals, sometimes succeeding, often failing, but always striving so long as he lives. Let us try to understand the history of these tendencies to strive, as they are revealed in the individual and the species; to understand more nearly our knowing, our imagining, our recollecting, our judging and reasoning, as they serve us in our strivings for the attainment of our goals.

As we progress with this task, let us cautiously extend the same principles of explanation to the animals of successively lower levels. And, when in this way we shall have gained some understanding of the life of the animalcule, we shall, perhaps, be able to begin to understand the physiology of the complex organism in its broader aspects. Instead of trying to illuminate human society by likening it to an animal mechanism, as was the fashion of the nineteenth century, we may find that we can profitably invert the process, that we can illuminate the complex organism by likening it to a well-organised harmonious human society, a society which can adjust itself to a thousand disturbances and can recover itself from grave disorders, just because and in so far as each member, endowed with limited powers of adaptation, steadfastly strives always to achieve the goal prescribed by his own nature and by his active relations with all his fellow-citizens.

But here we shall be met again by the cry of the timid psychologist. 'You are not scientific,' he will say, 'for you are disregarding the fundamental postulate of all science, namely, that all events are strictly determined, that mechanistic causation rules universally.' To this we can only reply by exhorting him once more to have courage, assuring him that 'Not all propositions made by all philosophers are true, neither does a proposition become true through being frequently repeated.'

Let us be content to postpone metaphysics and to start out from two indisputable empirical facts: first, the fact that sometimes men create new things, such as great works of art and literature and new scientific formulæ. Secondly, the fact that, when the normal man simply and strongly desires a certain end and perceives certain bodily movements to be means to that end, those movements follow upon that desire and that perception. Here are well-established empirical generalisations from which we may confidently start out, refusing to be held up by questions at present insoluble, such as—How can consciousness deflect the path of a single molecule in my brain? Answers to such questions are quite unnecessary as foundations for purposive psychology. It is in the highest degree probable that, as Science progresses, it will become clear that such insoluble questions have been wrongly stated and should never have been asked.

Let us not deny ourselves the right to build up a psychology that may be of use and value to our fellow-workers in the social sciences, because we cannot at present answer the most difficult of all questions. The physicist is equally nonplussed if you ask him comparable questions, such as—How does one molecule attract or repel another? What is the nature of chemical affinity? What is electricity? But he does not

suspend his researches because his fundamental conceptions and assumptions are disputable and disputed ; nor does he turn to some other branch of science in order to borrow from it others that have more prestige. Let us follow his example.

Let us gather our facts of human nature by objective and by introspective observation. Let us make our empirical generalisations and correlations of these facts, building up our own science in our own way. Let us boldly affirm that, just as the physical sciences do not proceed deductively from any system of exact abstract propositions, so also psychology, the most concrete of the sciences, is not required by any higher authority to accept or formulate any abstract propositions as an unchanging deductive basis.

It may be that eventually men of science will agree that there are in the universe two ultimately different kinds of process, the mechanistic and the purposive, the strictly determined and the creative, the physical and the mental. Or it may be that, eventually, one of these may be shown to be merely an appearance of the other, an appearance due to the present limitations and imperfections of our understanding. At present we cannot decide this issue.

But, if I attempt to guess at the future development of Science, I incline to follow the lead of the most powerful intellects of all ages, and to predict that, if such resolution of the two types of process into one shall ever be achieved, the purposive type that we regard as the expression of Mind will be found to be more real than the other.

SECTION K.—BOTANY.

PHYSIOLOGICAL ASPECTS OF PARASITISM.

ADDRESS BY

PROFESSOR V. H. BLACKMAN, Sc.D., F.R.S.,

PRESIDENT OF THE SECTION.

The President of the Association will have expressed the satisfaction which all the Sections feel in meeting for the fourth time in the history of the Association in the great Dominion of Canada. To Section K the almost overwhelming size of the country and the great diversity of vegetation, both natural and artificial, must have an especial appeal.

Last year the President of Section K had to deplore the loss of three prominent botanists. I am less unfortunate in that our loss this year is far lighter. We have, however, to regret the death of Thomas Frederick Cheeseman, a distinguished worker in systematic botany who devoted himself to the study of the flora of New Zealand.

In deciding on the subject of a Presidential Address, the vastness of Canada's agricultural and sylvicultural interests can hardly be overlooked, even in a section the interests of whose members are in the main those of pure botany. It appeared to me appropriate that if possible some aspect of pure botany should be chosen which would have at least implications in applied botany. The subject of disease is, of course, one of great moment wherever plants are massed together in artificial cultivation. Some aspect, therefore, of plant pathology seemed a fit subject for an address on such an occasion, since in it we have a branch of botany securely based on scientific interest and firmly buttressed by economic importance. Some consideration of disease in plants seemed peculiarly apposite also when it is recalled that at the last meeting of the British Association at Toronto, in 1897, the President of this Section was Professor Marshall Ward, the first English plant pathologist of the modern school. The value of his contributions to our knowledge of disease in plants is recognised by all; that he should have been cut off in his prime, British botanists will long deplore.

It is significant of the growth of botany in all its branches that Marshall Ward set himself as his presidential task a wide survey of the fields of mycology, parasitism, and fermentation. Needless to say, the task that any President of Section K can at the present time essay must be one of much smaller compass.

In the field of plant pathology which has been so assiduously cultivated of late years, attention has been mainly focussed on the study of the life-history and mode of infection of fungal and bacterial parasites, and on the methods of controlling infection. The relationship of host and parasite

and their mutual reactions have until recently secured but scant attention. It is some of these physiological aspects of parasitism that I propose to take as the subject of my address.

In dealing with any aspect of this branch of Botany one is faced by the fluidity of our conception of parasitism.[1] It may range from the simple relationship to its host of a Sooty Mould or of *Botrytis cinerea* to the complicated relationship found in the Uredineæ.

The physiological aspects of parasitism in the case of a fungus like *Botrytis cinerea* are apparently of the simplest when once it has entered the host. The cells of the host plant are killed in advance by the secretion of an enzyme of a pectinase type and the dead tissues serve as food for the parasite. On the other hand, in the case of the parasitism of fungi belonging to the Uredineæ and Erysiphaceæ (and probably the Ustilaginales, and possibly also the Exoascaceæ) we have a complicated relationship in which there is a definite physiological resistance of the host cells to the attack of the fungal organism. There is action and reaction, the balance of forces sways this way and that—in favour of the host or the invader—and there may for a time be an equilibrium in which the fungus is held in check but not vanquished.

The existence of this reaction between the host and parasite which we find in the Rust Fungi, and which I shall discuss more in detail later, has only been realised comparatively recently, and thus, on the botanical side, the physiological aspect of disease has been largely overlooked. Disease is abnormal physiology, and it is necessarily the result of the interaction of the physiological processes of the host and parasite. This interaction between the physiological processes of the two organisms has long been recognised in animal disease; it exhibits itself in the specific symptoms which are characteristic of disease in man and the higher animals generally. The specific symptoms of such diseases were recognised long before the ‘ germ basis ’ of disease was substantiated, and thus the attention of animal pathologists was inevitably turned towards a study of the physiological response of the affected organism. These special reactions are in general so clearly marked that the nature of an infectious disease in man can generally be determined without reference to the invading organism. In plants, on the other hand, the symptoms of parasitic disease are highly generalised, a large number of infectious diseases displaying the same symptoms. It is thus often very difficult, and sometimes impossible, to determine the nature of a plant disease without knowledge of the nature of the parasite. This distinction between diseases of plants and animals is, however, not a fundamental one. The point must be stressed that although the symptoms of different parasitic diseases may be superficially similar, yet the existence of physiological reactions of the host specific for each infection can hardly be doubted when once it is recognised that disease is abnormal physiology, the physiological processes of the host being modified by the physiological processes of the parasite. At the present time we are unable to distinguish the special reactions which the clash

[1] Parasite (παρὰ σῖτος) means etymologically ‘ beside the victuals.’ As Sir Ray Lankester has pointed out, it was the Greek term applied to those attending sacrifices to obtain food. It had no suggestion of meanness till rich men for purposes of display cultivated ‘ hangers-on.’ In its primary sense it can be used for any ‘ co-liver ’ whether or no it does harm.

of the two sets of processes must produce in the host. With improvements in our methods of biophysical and biochemical analysis we may anticipate a time when these hidden reactions may be revealed and a new basis for the classification of plant diseases established.

Another striking difference between animal and plant pathology which is worth insisting upon is that relating to disease resistance. Disease resistance is shown both in plants and animals, but the particular type of immunity which has been most clearly studied by the workers on the animal side is *acquired* immunity, *i.e.* that type of specific resistance which is the result of one attack of a specific disease. Such immunity must have forced itself on man's attention from very early times, and it is by a study of such resistance that animal bacteriologists—building firmly on the work of Pasteur—have developed the modern treatment of disease by the injection of dead organisms and of the blood fluid of animals containing suitable antibodies. The development of such vaccine and serum therapy should, I think, be rightly considered as one of the most remarkable achievements of modern biology.

On the other hand, the problem of immunity in plants is a far more difficult one than that with which the animal pathologist is faced. The acquired immunity due to one attack of a disease which is so common in animals is unfortunately quite unknown in plants, at least in relation to definite disease. The modern view of recovery from infectious bacterial disease in animals is that it is due to a very well-marked and highly specialised reaction of the invaded organism. Part at least of the reaction is the development of antibodies which neutralise the toxins produced by the invading bacteria and help to bring about their death. It is true that in the Erysiphaceæ and the Uredineæ and in certain cases of endotrophic mycorhiza, and in the well-known orchid fungus, the invaded cells show a very marked reaction which may lead to the death, and sometimes to the digestion later, of the invading hyphæ. These, however are not cases of ordinary disease and the cells show no acquired resistance.

Again, whatever may be the behaviour of individual plant cells when attacked, one never finds that general bodily reaction which is so marked and characteristic of many infectious diseases in the higher animals. The parts of the plants are, of course, much less highly correlated than those of the animal body; there is no circulating blood stream by which the most distant cells of the body can with great rapidity be brought into physiological relationship. Even in the case of the highly specialised parasitism of the Rust Fungi, where there are obvious complex physiological reactions between host and parasite, we find no general reaction by the plant, but cells or small groups of cells carry on a struggle with the invading bacteria and hyphæ apparently in complete independence. It follows that in the absence of any suitable reservoir—such as the blood stream of animals supplies—in which toxins and antitoxins may be sought, the likelihood of their demonstrations, should they be produced, is very slight. The absence in plants of a general bodily reaction to disease would seem also to preclude the possibility of the application to them of serum therapy. If, in spite of the absence from plants of the acquired resistance which is the basis of serum therapy in animals, such sera could be prepared, there would be the great difficulty of distributing such substances throughout the plant. Another and apparently insuperable barrier to

success would be the continued development exhibited by the plant, which would necessitate the endowment of the plant body not only with acquired immunity to the disease in question, but an immunity of such a type as would be passed on to the newly developing organs. A reaction of the nature of inherited, acquired immunity would have to be attained, and this in view of the experience of animal bacteriologists is unlikely of realisation.

Immunity and resistance to diseases are, of course, well known in plants, but they are of the nature of *natural* immunity. Plant pathologists need not, I think, reproach themselves for the small progress that has been made in the elucidation of the nature of this resistance, for the basis of natural immunity in animals remains still very obscure, although the physiological field has been worked for a much longer term of years by animal than by plant pathologists.

Some of the processes concerned in the achievement of parasitism in plants may now be considered. The question of the mode of entry of a parasitic organism into a host plant is one of great physiological interest and importance; for a barrier which the would-be invader cannot pass is one of the most obvious means of defence against fungal attack. Apart from entry through wounds, there are two chief modes of entry of the aerial parts of plants, either through a stomatal pore or by actual penetration of the superficial cells of the host. The entry through the stoma, at least in the case of a germ-tube, is clearly the most facile one, and it is somewhat of a biological puzzle that any germ-tubes should follow the hard road of epidermal-cell-penetration rather than the easy path of stomatal invasion where moisture and food material can so easily be obtained.[2] Yet the germ-tubes of *Botrytis*, *Colletotrichum*, and *Fusicladium*, for example, and the germ-tubes of the sporidia of Uredineæ, apparently never enter the open stoma but proceed to bore their way laboriously through the epidermis. The case of the Rust Fungi just mentioned is particularly striking, for the germ-tubes of the uredospores and æcidiospores on the other hand invariably enter through the stomata.

The nature of the reaction which brings about the stomatal type of entry is still very obscure. It is frequently assumed that the entry is in response to some hydrotropic reaction, that the germ-tube passing over the stomata finds itself exposed to a stream of water vapour diffusing out of the pore and thus a tropistic reaction is produced. Balls, some years ago, showed that the uredospores of Rust Fungi when placed on a thin perforated sheet of rubber above a water surface developed germ-tubes which passed through the perforations towards the water. This interesting experiment demonstrates that the germ-tubes in question are capable of hydrotropic curvature, but it does not show that the entry into the stoma is due to such a reaction. In the experiment with the rubber sheet there must have been marked differences in the concentration of water vapour on the sides of the membrane. In the case of a germinating spore on the surface of a leaf and under the conditions in which infection usually occurs, the differences in concentration on the two sides must be very slight. The surface of the leaf would be covered with layers of air very nearly

[2] A germ-tube without the capacity for penetration of the epidermis would be at a disadvantage on a non-stomatal surface.

saturated, and the germ-tubes in question are in close contact with the surface of the epidermal cells through which a certain amount of cuticular transpiration is occurring.[3]

The possibility that the entry through the stomata is due to a chemotropic response to some volatile substance (such as a volatile organic acid, aldehyde or ester) emanating from the leaf tissue and diffusing through the stomata ought not to be overlooked. That volatile substances from plant tissues can stimulate or retard germination has been shown by Brown[4] and by Neger,[5] and the ascription by Cooley of 'scald' in apples to the accumulation in closed chambers of acetaldehyde volatilising from the fruit tissue is well known. It would seem also that a positive thermotropic reaction ought not to be overlooked in considering the physiological aspects of fungal penetration of the host. Penetration of the surface of the leaf by a germ-tube occurs under conditions of high humidity and very slight air movement, conditions which would tend to reduce the heat losses of the leaf to a low level. In such circumstances the respiratory processes of the tissue might easily be responsible for a leaf temperature of the order of 1° C. above that of the air.[6] The penetration by germ-tubes of such surfaces as those of gelatine and collodion show, however, that this cannot be a main factor.

The question of the physiological processes concerned in the other method of entry, that through the epidermal cell, also requires further elucidation, and the conditions surrounding a germ-tube developing in a drop of water on a leaf may be considered. When the work of Miyoshi on the chemotropism of fungi and of pollen tubes appeared in 1894, it was naturally assumed that entry was due to a positive chemotropic response of the germ-tube or fungal hypha to some substance diffusing from the surface cells of the host into the drop containing the germinating spores. Considerable doubt, however, was thrown on the interpretation placed by Miyoshi on his results by the work of Clarke and of Fulton, who demonstrated that fungi showed a marked negative chemotropism to their own waste products. It remained questionable then as to whether fungi exhibited any positive chemotropism towards nutritive substances. Graves,[7] however, by allowing for the negative chemotropism towards staling products and giving it a rough quantitive measure, was able to show that, in addition to this negative reaction, there is a definite positive reaction towards such substances as cane sugar and turnip-juice. A tropism of

[3] The cogency of this argument is reduced by the fact that the same difficulty arises in the case of all chemotropic reactions. The differences in the concentration of a sugar on the two sides of a hyphal tip, which responds to a diffusion gradient by a curvature, must in many cases be exceedingly small. It seems possible that in all such cases other factors may be at work.

[4] W. Brown: 'Studies in the Physiology of Parasitism IX.' *Annals of Botany*, xxxvi., 285, 1922.

[5] F. W. Neger: 'Förderung der Keimung von Pilzsporen durch Exhalationen von Pflanzenteilen.' *Naturw. Zeit. f. Land- u. Forstwirtschaft*, ii., 484, 1904.

[6] For the latest leaf-temperature measurements of crop plants see E. C. Miller and A. R. Saunders (*J. Agric. Res.*, XXVI., 15-43, 1923), who have made 20,000 observations of such temperatures. Except in direct sunlight and in wilted leaves they find only slight differences between the temperature of the air and of the leaf, but, as stated above, the conditions suitable for infection are of a special kind.

[7] A. H. Graves: 'Chemotropism of *Rhizopus nigricans*.' *Botan. Gazette*, lxii., 337, 1916.

this kind seems, however, insufficient to explain the reaction of germ-tubes towards the surface of a host plant. The germ-tubes of *Botrytis* developing in a drop of turnip-juice will penetrate the surface of a bean leaf; and as the turnip contains substances which strongly attract germ-tubes (at least those of *Rhizopus*), it seems unlikely that the concentration of any attractive substances which may diffuse through the cuticle would be sufficient to produce a stronger response than that due to the comparatively high concentration of the active substances in the drop. Again, Dr. Brown has shown in an unpublished observation that germ-tubes of *Botrytis* growing in turnip-juice will penetrate a thin sheet of paraffin (about 10μ in thickness) which is floating on the same fluid. In such cases where a positive chemotropism appears very unlikely, the only other possible reactions which might be at work seem to be a negative chemotropism of the germ-tubes towards its own waste products, or a positive reaction towards the surface with which the germ-tube is in contact. If such a negative reaction were the main factor in penetration, one would expect the germ-tubes of any fungus, such as *Penicillium* or *Rhizopus*, to enter a bean leaf from turnip-juice; this, however, does not occur. Furthermore,

Fig. 1.

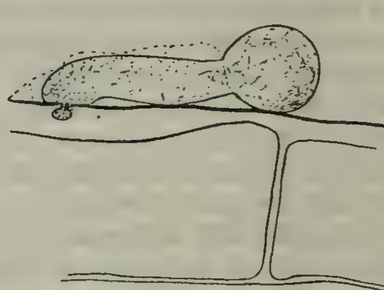


Fig. 2.

it may be argued[8] that there will be a higher rather than a lower concentration of waste products on the side of the germ-tube towards the substratum (fig. 1), owing to the difficulty of the escape of such products in this direction. The question really resolves itself into that of the nature of the waste products and their relative rate of diffusion through the water of the drop on the one hand, and through the epidermal cell-wall on the other. If the waste products can diffuse with fair rapidity through the cuticle and epidermal cell-wall and so escape into the general body of the leaf, or if they are taken up in some way (possibly by adsorption) by the host cells, then it is quite possible that the concentration on the lower side towards the host tissue may be such as to lead to a growth towards that host surface. The probability of a negative chemotropism of this k nd playing any considerable part in the responses of the germ-tube which lead to penetration does not, however, seem very strong. Such a chemotropism certainly does not prevent the germ-tubes of such fungi as *Botrytis* and *Colletotrichum* fixing themselves firmly to an impermeable glass surface.

If both positive and negative chemotropism are excluded it would seem that a contact stimulus must play the major part in the entry of a parasite

[8] As Dr. W. Brown has suggested to me.

into the epidermis of the host. This response to contact with a solid substratum is usually termed thigmotropism, though stereotropism would seem to be the more satisfactory term. That the germ-tubes and hyphæ of many fungi (such as *Botrytis*, *Colletotrichum*, *Sclerotinia Libertiana*) exhibit a stereotropic response is, of course, easily demonstrated by growth of such fungi in hanging drops on a glass surface. The question then arises as to whether stereotropism is the sole or main cause of the growth response which leads to entry. If a tropism of this kind be the main factor, one would expect the penetration of any surface (such as a leaf) of not too great resistance by any germ-tube responding to a contact stimulus, *i.e.* an entry quite non-specific.[9] At present the data available do not seem sufficient to answer this question. The problem of the mechanism of infection requires investigation from this particular angle. Some light on the matter could no doubt be obtained by germinating together the spores of two parasitic fungi, say A and B, first on the host of A (which B does not infect), and then on the host of B (which A does not infect), and comparing accurately their responses on the two substrata. It is the melancholy experience of physiological work that a simple explanation of any process is almost certain to be wrong. It would therefore seem unlikely that stereotropism alone is responsible for penetration. How complex is the relationship is shown by another observation of Dr. Brown's that germ-tubes of *Botrytis cinerea* are unable to penetrate the epidermis of an uninfected leaf of *Eucharis amazonica*, but they will bore through it when the mesophyll tissue below is cut away, even when the leaf so treated is 'backed' with agar.

The question of the actual mechanism of entry is of considerable physiological interest. A number of studies by Brown, Blackman and Welsford, Boyle, and Dey[10] have been published which bring forward evidence for the view that the entry of a germ-tube through the cuticle of the host is a purely mechanical process in which enzymes play no part. The evidence for this is in part directly observational. When the process of entry is carefully followed in such forms as *Botrytis cinerea*, *Colletotrichum*, *Sclerotinia Libertiana*, the sporidia of *Puccinia graminis*, it is found that the germ-tubes or appressorea become firmly attached to the surface of the host before entry, and no swelling of the cuticle can be observed prior to entry. Furthermore, entry is usually by a very fine infecting hypha (fig. 2), and at the actual point of entry of such hypha there is no rounding of the contours of the cuticle as we should expect if enzymes were at work. There is also the additional point that no enzyme is known that is able to dissolve cuticle. The injection into an organ, such as a leaf, of an extract of the germ-tubes of *Botrytis* is a very convenient way of preparing sheets of cuticular material. The resistance of cuticle to bacterial attack is well shown by the composition of brown coal, which often consists very largely of cuticular material.

If the germ-tube is to exert sufficient force to bore its way through the

[9] In the case of the Uredineæ the entry through a stoma is quite non-specific, for, as Miss Gibson showed, the germ-tube of almost any Uredine will enter the stoma of almost any leaf, but the establishment of parasitism depends upon the suitability of the host.

[10] 'Studies in the Physiology of Parasitism.' *Annals of Botany*, xxix.-xxxv., 1915-1921.

resistant cuticle, it is evident that it must have some *point d'appui* against which the force can be expected. There must clearly be some adhesion of the germ-tube to the substratum or else the development of an outgrowth from the germ-tube will result, not in penetration, but merely in the forcing the tube away from the surface. It was originally suggested[11] that the gelatinous sheath which can be demonstrated round the germ-tubes of *Botrytis cinerea*, and of some other parasitic fungi, is the main factor in the close attachment of the tube to the substratum. Further consideration, however, suggests that the essential preliminary to penetration is the close adhesion of the tip of the germ-tube to the surface to be penetrated. This close adhesion to the surface to be penetrated is a constant feature of epidermal infection, whether we are dealing with *Botrytis cinerea, Sclerotinia Libertiana, Puccinia graminis* (sporidia), or the case of *Colletotrichum* where the tip of the germ-tube becomes converted into a dark-coloured, thick-walled appressorium from which the infection-tube grows out later. In this adhesion the two gelatinous sheaths may play some part, but when one considers the ' microscopic ' closeness of the contact it would seem clear that molecular forces must be at work, so that once they are brought into such close relationship the two surfaces would necessarily adhere.[12] This sheath may, however, be of use in preventing the germ-tube from being easily washed off the surface on which it is growing and also in giving the germ-tube the attachment necessary if the tip is to be pressed firmly against the surface of the leaf or other organ. Once, however, the two surfaces are pressed together they should adhere in the manner indicated.

It will be noted that the adhering surface from which the infection tube grows out is in general large compared with the cross section of the actual peg-like infection hypha which bores through the cuticle (fig. 2). This hypha is very small, and in the case of sporidial infection in *Puccinia* and infection by *Synchytrium endobioticum* it is of extreme tenuity, so that in the epidermal wall itself it can only just be observed. The absolute pressure required to push such a minute infection hypha through the wall would be very small, and the forces of adhesion which hold the tip of the germ-tube (or the body of the zoospore in *S. endobioticum*) to the surface of the host cell would seem to be more than sufficient to resist the *back* pressure resulting from the outgrowth of the infection tube. The processes concerned in the development of this outgrowth are probably very similar to those concerned with the development of a lateral branch on a hypha. If one assumes that the cell-wall of the germ-tube becomes softened over the appropriate area, then the osmotic pressure of the contents of the germ-tube should be more than sufficient to overcome the resistance of the cuticle and the sub-cuticular layers of the cell-wall. It is interesting to note that Hawkins and Harvey conclude that mechanical puncture is the method by which *Pythium debaryanum* passes after entry through the ordinary cell-walls of the potato tuber,[13] and that resistance of the tuber cells to

[11] Blackman and Welsford: ' Infection by *Botrytis cinerea.*' *Annals of Botany*, xxx., 389, 1916.

[12] This suggestion that such molecular forces come into play was originally put forward in a discussion by Dr. A. L. Balls.

[13] L. A. Hawkins and R. B. Harvey: ' Physiological Study of the Parasitism of *Pythium debaryanum* Hesse, on the Potato Tuber.' *J. Agric. Res.*, XVIII., 275, 1919.

mechanical puncture and resistance to attack by this fungus are definitely correlated. These authors also determined by plasmolysis the osmotic pressure of the fungal hypha and the pressure required to perforate the tissues, and they found that in all cases but one the osmotic pressure was sufficient to allow of puncture of the wall of the potato cell by the hypha.

The question of the nutritive conditions to which the germ-tube is exposed when developing on the host tissue is evidently of importance in infection. A strong well-developed germ-tube is more likely to succeed in penetrating the host tissues than a weakly one. This is in agreement with the experience that with forms like *Botrytis* and *Colletotrichum* it is easier to get infection from drops of weak culture medium than from water. In nature, however, the 'infection drop' must usually consist of rain or dew. That substances which are able to stimulate the growth of the germ-tubes can diffuse from the underlying host tissue into the infection drop has been shown by W. Brown (*loc. cit.* 1916). How considerable may be the amount of substances diffusing into water on the surface of a plant is shown by the analysis of dew from cotton plants given by Smith. No less a quantity than 1,300 c.c. was collected, and it was found to have a content of total solids of 1,023 parts per million, most of the solids consisting of calcium and magnesium carbonates.[14]

The observations of R. J. Noble on Flag Smut of wheat (*Urocystis tritici*) provide another example of the stimulating action of minute amounts of tissue extracts. The addition of a few thin slices of wheat tissue to water in which well-soaked spores of this fungus are lying increases very markedly the amount of germination over that in ordinary culture media. The action is not specific, for tissues of rye, barley, flax, etc., will produce the same effect, though to a less degree. The distillate from watery extracts of wheat seedlings was also found to act, so the stimulating substance is volatile, and possibly similar to the substances observed by Brown, to which reference has already been made.[15]

It is clear from such observations as these that the conidium may find in the infection drop on the leaf a supply of nutritive or stimulating substances. Of the chemotropic power of these substances there may be some doubt, but of their importance in the production of vigorous germ-tubes well equipped for the work of cell-wall penetration there can be little question. In the study of the mechanism of entry by various fungi into the epidermal tissues of their host undertaken by the writers already mentioned, not only was there no evidence of solution of the cuticle, but until the cuticle had been ruptured there was no sign of enzymatic action on the cell-wall layers beneath. This suggests that cell-wall dissolving enzymes are unable to diffuse through the cuticle. It should be pointed out, however, that Smith,[16] in his study of the haustoria of the Erysiphaceæ, describes a change in the staining reaction of the cell wall below a hypha before the cuticle had been ruptured. Miss Allen also describes a marked

[14] C. M. Smith: 'Excretion from Leaves as a Factor in Arsenical Injury.' *J. Agric. Res.*, XXVI., 191-4, 1923. The analysis in full, in parts per million, was S_1O_2, 13; oxides of Iron and Aluminium, 17; SO_3, 26; Cl, 19; CaO, 529; MgO, 100: CO (by titration), 618.

[15] R. J. Noble: 'Studies on *Urocystis tritici* Koern, the Organism causing Flag Smut of Wheat.' *Phytopathology*, 13, 127, 1923.

[16] G. Smith: 'A Study of the Haustoria of the Erysiphaceæ.' *Bot. Gaz.*, 16, 1905.

change in the cell walls of the guard cells lying below the appressorium of *P. graminis tritici*. These guard cells had not been penetrated, the hypha passing between them to form the substomatal vesicle, and yet the walls of these cells became markedly altered in their reaction to stains. It may be that both these cases demonstrate the action of enzymes derived from the fungus, for diffusibility and non-diffusibility are only questions of degree ; it may be, on the other hand, that these cell-wall changes are due to changes produced in the host cell as a result of the entry into the cell of poisonous fungal products more diffusible than are enzymes.

The question may now be considered as to what progress has been made by plant pathologists in elucidating the quality of natural immunity. As has already been stated, the problem of natural immunity is an extremely difficult one which animal pathologists on their side have found very baffling. It can be said, however, that some success has been achieved in a preliminary analysis of some cases of natural disease resistance in plants. As is so common in biological work, the difficulty of solution is greatly enhanced by the variety in the types of disease resistance. In many cases resistance to disease is achieved by keeping the enemy out by some physical barrier, or possibly by some special chemical environment in the absence of such a barrier. In other cases the parasite achieves entry and in a susceptible host makes its way through the tissues comparatively unimpeded, while in a resistant the entry calls forth a wound reaction leading to the production of cork which hinders or sets a complete bar to the progress of the invader. A good example of these two types of behaviour is that of *Fusarium Lini* when attacking susceptible or resistant forms of flax. In one case the physiological processes of the resistant host interacting with those of the fungus lead to abundant cork-formation ; in the other they do not. In what manner the physiological processes of the two types of host differ we cannot at present say. Nor can we at present explain why the harmonious relationship, which in the case of the cereal Smuts is established for most of the vegetative life of the host, suddenly breaks down on the development of the inflorescence. Is the metabolism of the cells of the developing reproductive organs so markedly different from that of the meristematic cells that the fungus is stimulated into active development and parasitism ? It would seem likely that a further knowledge of the nature of the 'physiological gradients' between the parts of plants would throw some light upon the peculiar relations of host and parasite in the cereal Smuts.

How elusive may be the factors underlying resistance is exemplified by the observations of Walker [17] on Onion Smudge due to *Colletotrichum circinans*. He found that onion bulbs with coloured outer scales were usually highly resistant, while white varieties were in general susceptible, and, furthermore, a watery extract of dry outer scales of the coloured onions is a marked toxic to the spores and mycelium of the fungus. On further examination it was found that although the internal white scales can be infected with ease, yet an extract of these inhibits the germination of the conidia and also retards the development of the mycelium. The volatile 'onion oil' seems responsible for the inhibition and retardation, yet when the fungus is growing in the host tissue there is no such action.

[17] J. C. Walker ; 'Disease Resistance to Onion Smudge.' *J. Agric. Res.*, XXIV., 1019, 1923.

It is only in the Erysiphaceæ and Uredineæ that we have knowledge of any cell reactions (though not of any general reaction of the plant body) comparable with those occurring in the infectious diseases of the higher animals. In these two groups the phenomenon of so-called specialisation of parasitism is well marked, and it is a comparative study of the behaviour of the biologic forms of the parasite on susceptible and resistant hosts that has been most fruitful. As has been known for some time, the normal relation of host and parasite in the mildews and rusts is, in the early stages of infection, one in which the fungus develops at the expense of the host cells; these, however, are not killed but stimulated to active development. De Bary observed long ago that the mildewed leaf may retain its green colour longer than the uninfected one. Salmon observed some years ago that the conidia of *Erysipha graminis* when growing on other than their normal host might send down haustoria into the epidermal cells, but such absorbing organs were short-lived. Neger[19] has recently investigated more closely the result of sowing upon the leaves of *Hieracium* of the conidia of *E. Cichoracearum* from *Sonchus asper*. The germ-tubes send into the epidermal cells outgrowths which start to produce haustoria. In contrast with infection of the normal host, the cells react markedly; they become filled with a gum-like mass which encapsules the haustoria. The epidermal cells then lose their turgor, die, and the development of the fungus is stayed. A leaf sprayed with suspension of such conidia appears as if it had been sprinkled with minute drops of a corrosive fluid. However, it is in relation to the cereal rusts that we have the clearest picture—in its purely superficial aspects at least—of the nature of resistance. With the discovery by Professor Biffen that resistance to the attack of *Puccinia glumarum* was associated with a single Mendelian factor, attention was naturally turned to the question of the nature of this resistance. Miss Marryat, comparing in Professor Biffen's laboratory the susceptible Einkorn and the resistant Michigan Bronze wheats, made the surprising discovery that the resistance was in one sense no resistance at all.[20]

The variety Einkorn was not able to keep the parasite out, for the hyphæ attacked the mesophyll cells, but the invaded leaf-cells—instead of establishing an harmonious working relationship with the mycelium as with Michigan Bronze--react very strongly, with the result that both they and the invading hyphæ are killed. The course of infection is thus stayed as a result of this *hypersensitiveness* of the host. The result with *P. glumarum* was later extended to *P. graminis*. The striking and assiduous work of Stakman and his co-workers has revealed to us that even *P. graminis* forma *tritici* consists of twenty or thirty different strains with a widely varying range of susceptibility and resistance among the different varieties of wheats. Stakman * in 1915 was able to confirm the violence of the reaction when strains of this form are sown on a resistant host; hypersensitiveness here also is the key to resistance. Last year

[19] F. W. Neger: 'Mehltaupilze—eine Art von gedultete Symbiose.' *Flora*, CXVI., 331, 1923.

[20] D. C. E. Marryat: 'Notes on the Infection and Histology of Two Wheats immune to the Attack of *Puccinia glumarum*.' *J. Agric. Science*, II., 129, 1907.

* E. C. Stakman: 'Relation between *Puccinia graminis* and Plants highly resistant to its attack.' *J. Agric. Res.*, V., 193, 1915.

Miss Allen [21] published a very careful and detailed cytological study of the infection of susceptible and immune wheats by forms III. and XIX. of *P. graminis tritici.* Mindum wheat is immune to form III. and Kanred to form XIX., so the behaviour of these two wheats was compared with that of other susceptible varieties. When Mindum is infected with the uredospores of form III. an appressorium is formed over the guard cells and entry occurs in the normal way through the stoma. Usually the first haustorium from the infection hypha develops in a mesophyll cell and its formation is the signal for a violent reaction on the part of this cell. The host-cell contents, including the cytoplasm, nucleus and plastids, flow rapidly towards the haustorium and become massed around it, forming apparently a sheath to the haustorium. Of the haustorium and host-cell cytoplasm Miss Allen states 'each seems to be toxic to the other ; at least, both die very soon.' The haustorium and its cytoplasmic sheath appear to be partially digested. The infection hypha is not killed by this reaction to the first formed haustorium, but only checked ; it may develop a few other haustoria in other host cells which are similarly killed ; finally the limited resources of the hypha are exhausted and it succumbs.

From a single infection only a small number of cells, about five or six, are killed by being entered directly by the fungus. The 'fleck' visible to the naked eye which is the sign of an attack successfully repelled consists of a much larger number of dead or damaged cells. This is explained by the fact that the violent *primary* effect due to entry is followed by a mild *secondary* effect on the cells surrounding the area of cells killed by entry. These neighbouring cells in a region 3-4 cells deep become plasmolysed and shrunken, and some of them show marked swelling of the walls.

Although in the cereal rusts we have the most complex reaction to attack by an invading organism which has been observed in plants, we find very few phenomena analogous with the response to infectious disease of higher animals. When the susceptible forms are attacked we find no spontaneous cure, no recovery of the attacked cells. We have no evidence in the resistant forms of the productions of antibodies in either the susceptible or resistant forms ; the death of the haustoria may be simply due to the death of the host cells in which they lie. It is true that we have a digestion of the haustorium, but this 'phagocytosis'—since the digestion of the haustorium is associated with the digestion of the host-cell contents and takes place after the death of that host cell—may be nothing more than an effect of autolysis.[22] Again, no general bodily reaction of the plant is apparent, each infection is highly localised, and each group of host cells fights a solitary battle independent of its neighbours. No analysis of plant resistance on the lines found so successful in animal disease can be achieved at present, nor is it likely in the future in view of the

[21] R. F. Allen : 'Cytological Studies of Infection of Baart, Kanred and Mindum Wheats by *Puccinia graminis tritici.*' *J. Agric. Res.*, XXVI., 571, 1923.

[22] It is true that in such peculiar symbiotic relationships as those of the orchid fungus and endotrophic mycorhiza—cases which do not fall into the category of ordinary disease—we do find digestion of invading fungal hyphæ by living active host cells. Such cells are, however, far from acquiring any resistance by such phagocytosis, for it has been observed both in orchids and in mycorhiza that host cells which have successfully coped with one attack by the process of digestion may be invaded again (*vide* Rivett, *Annals of Bot.*, XXXVIII., 1924).

marked dissimilarities between the two. As has already been insisted upon, the immunity which has to be explained in plants is *natural*, while that resistance which animal pathologists have explained, at least in part, is *acquired*. The explanation of the difference in the behaviour of the mesophyll cells of the susceptible and resistant wheat must lie in the difference in the normal physiological processes of the two. This demonstrates how dependent is plant pathology for its advance on plant physiology. The differences do not seem to be merely differences specific to the wheat varieties, differences such as would be common to all the cells of the plant—or if there are such differences they are easily masked by other factors—for Miss Allen observed that while the mesophyll cells of the resistant wheat reacted violently when invaded, yet if an epidermal cell was attacked the haustorium developed might attain its full size and function for some time. It is evident that we must await fuller knowledge of the normal physiological processes of the cells of the two varieties, and of the physiological differences between the cells of different tissues, before much light will be thrown on the nature of such immunity as is met with in the Erysiphaceæ and Uredineæ.

A consideration of the nature of disease resistance in plants thus leaves us with no expectation of finding means for endowing plants with artificial disease resistance. Apart from the protection of plants from infection by the use of fungicides, etc., our chief hope of combating disease lies in two directions—one, that of breeding disease-resistant forms of plants, and the other that of the enhancement of the natural resistance of the plant. In breeding for disease resistance, marked successes have been obtained since Biffen's fundamental work on Mendelian inheritance of resistance to *Puccinia glumarum*. In a number of cases of rust resistance in cereals since examined, immunity has been found to be dominant over susceptibility. The question of breeding wheats resistant to *P. graminis*, which is, of course, one of great economic importance, has been much complicated by the discovery, to which reference has already been made, that a very large number of biologic forms or strains of *P. graminis tritici* exist; high resistance to attack by some of the strain may be associated with marked susceptibility to attack by other strains. Aamodt, however, claims to have demonstrated that it is possible to build up synthetically a wheat which will be resistant to a large number of biologic forms of *P. graminis tritici*.[23]

Although we find that the field of control of plant diseases by substances lethal to fungi and by the breeding of disease-resistant host plants is being actively cultivated at the present time, yet the field of inquiry as to the effect of environment on the liability of plants to diseases is comparatively unworked. The view that immune plants, such as cereals immune to rust, might suddenly lose their resistance under new conditions is now no longer held; the apparent loss of resistance is probably in part explicable by the fact that the host in its new environment has been subjected to attack by another biologic form of the fungus than that to which it is resistant. In spite of this, however, it is perfectly clear that with numerous diseases the degree of natural resistance is markedly affected by the conditions of

[23] O. S. Aamodt: 'The Inheritance of Growth Habit and Resistance to Stem Rust in a Cross between Two Varieties of Common Wheat.' *J. Agric. Res.*, XXIV., 457, 1923.

cultivation. In some classes of disease, such as the Rusts, the intensity of attack tends to rise with the increased vigour of the plant, and Melhus [24] found that with unhealthy plants it was almost impossible to obtain satisfactory infection by *Cystopus candidus.*

On the other hand, there is a large class of infectious diseases in which the degree of natural resistance can be markedly enhanced by good cultivation. Under good conditions such diseases, which with Nowell [25] may be termed 'Debility diseases,' are of little importance; they only become serious when the crops are growing under unfavourable conditions. Diseases of this class are usually caused by saprophytes which are only weakly parasitic. The question of the nature of the changes occurring in the plant in conditions of so-called debility are quite unknown. The problem is sure to be a complex one, but it is possible that one of the factors may be an increased permeability of the superficial tissues of the less vigorous plants, so that the spores on the surface of the host find conditions especially favourable for vigorous growth. In addition to the relation of general health to the incidence of certain plant diseases, we have the undoubted effect of certain fertilisers, such as potash, in reducing the intensity of fungal attack. Exploration of such fields of physiological research, though no doubt the difficulties of investigation are considerable, should certainly provide results of great scientific interest. A clue to the nature of the changes occurring in plants which can reduce their liability to disease may also open the way to the enhancement of natural resistance by other and possibly more economical ways. Clearly it is on plant physiology that plant pathology is largely dependent, not only for the elucidation of the relationship of host and parasite, but also for fundamental scientific knowledge which may profoundly affect economic practice.

[24] J. E. Melhus: 'Experiments on Spore Germination and Infection in certain Species of Oomycetes.' *Wisconsin Agr. Exp. Stat. Bull.*, 15, 1911.

[25] Nowell: 'Diseases of Crop Plants in the Lesser Antilles.' 1923.

SECTION L.—EDUCATIONAL SCIENCE.

THE NATURE AND CONDITIONS OF ACADEMIC FREEDOM IN UNIVERSITIES.

ADDRESS BY

PRINCIPAL ERNEST BARKER, M.A., D.Litt., LL.D.,

PRESIDENT OF THE SECTION.

Freedom, in that sphere of politics in which we use the word most often, may be an attribute either of the individual, in his thought and action within the community, or of the community itself, in its relations and standing among other communities. It may be a right of the citizen, or it may be an attribute of the State. In the intellectual sphere, with which we are here concerned, freedom may similarly be an attribute either of the individual teacher, in his teaching and speaking and writing, or of the whole academic community, in its relation to the general environment of political authorities and economic interests in which it is set. These two freedoms of the mind are almost correlative. We may almost say that a free professoriate means a free academic community; and, conversely, that a free academic community means a free professoriate. But there are qualifications and limitations of this identity. A university which is free from control by the general social environment may seek to control unduly its own professors in the name of its own alleged freedom. We cannot, after all, treat academic freedom under a single head; and in any discussion of the subject we must distinguish the freedom of the teacher from that of the university.

The freedom of the teacher, like all freedom that is other than mere license and anarchy, must exist within a framework of law, because it exists within the framework of an institution, and because, again, any institution involves some system of law. The law of an academic institution is partly an unwritten code of professional conduct, and partly, it may be, a written set of principles and tenets. The unwritten code forbids a teacher to use his class-room as a place for the inculcation of partisan views. It may be difficult to draw a clear line of division between what is partisan and what is impartial; but we should all agree that there *is* a line, and that, in his class-room, a professor is not free to wander on the further side of that line. What he may do outside the class-room is another matter, which we must consider later. A written set of tenets and principles is comparatively rare; but it may obviously exist, for example in a theological college or a general college founded on a confessional basis. A professor who has subscribed to these tenets has voluntarily limited his freedom by that subscription. The college to which I belong at one time required a written subscription from its teachers to the Thirty-nine Articles.

When F. D. Maurice was deprived of his chair, in 1853, for his views on eternal punishment, it was not definitely stated in the resolution of the governing body that he had contravened those Articles. It was stated, in vaguer terms, that his opinions were 'of dangerous tendency . . . calculated to unsettle the minds of the theological students . . . detrimental to the usefulness of the college.' None the less, though the action taken by the governing body was not grounded, and perhaps could not have been grounded, on a definite contravention of the Thirty-nine Articles, the existence of a rule of subscription to those Articles was the real basis of that action.

A much more difficult question arises when we turn to consider the action of a professor outside his class-room. Here, again, the case of F. D. Maurice occurs to the mind. He was attacked in 1851, and virtually censured, though not deprived of his chair, for his connection with the Christian Socialist movement. The case is curiously typical, and curiously apposite to our modern difficulties, even though it occurred over seventy years ago. Croker had launched the attack in the Press, and besides attacking Maurice he had drawn the college into the issue, by stating that 'it added to his surprise to find the holder of such views occupying the professorial chair . . . in King's College, London.' Some general considerations of a large pertinence are suggested by Croker's action and words. The Press *may* defend, and by its own position as a natural champion of freedom of expression of opinion it will often actually defend, the freedom of a professor; but just because it is necessarily set on publicity, it is also a danger to that freedom. It does not help the free course of thought that its delicate difficulties should be cried in the streets. The Press, again, will always attach the label 'professor,' and the name of his institution, when it chances to mention in any connection an ordinary citizen who is also a professor at any institution. By such attachment a sad result is entailed. If the citizen who is also a professor speaks on a public issue, he is made to involve his institution in what he says. If what he says is unpopular, he may make his institution unpopular: it may lose students: it may lose benefactions.[1] What is the institution to do? Should it make a rule, such as the Principal of King's College seemed to suggest in 1851, 'that you will do your utmost to bear in mind the duty and importance of not compromising the College'? If it makes such a rule, it will be bound to define what is compromising, and it will be bound in the last resort to enforce its definition. In order to prevent itself from being compromised, it will compromise itself terribly. A professor may compromise it in part: it will compromise itself as a whole. A wise president of a great American University—President Lowell of Harvard—has put the point admirably in his annual report for the Session 1916-1917: 'If a University or College censors what its professors may say . . . it thereby assumes responsibility for that which it permits them to say. This is logical and inevitable, but it is a responsibility which an institution of learning would be very unwise in assuming.' A wise university will run any risk of being compromised by its members rather than compromise its entire self.

But if the university is wise to tolerate, the professor is wise to be severely moderate and master of himself. It is true that he is a citizen,

[1] This is stated, or implied, by the Principal and Council of King's College in 1851. See the *Life of F. D. Maurice*, by F. Maurice, ii., p. 80, p. 98, p. 101.

and has every right of an ordinary citizen—engineer, lawyer, doctor or banker—to express his opinions on civic affairs. It may even be urged that he has a special right to express himself, in virtue of the possession of special knowledge ; and it is possible to contend that he has even a duty to aid the judgment of the community by contributing his knowledge and his opinion in vexed questions which lie specially within the ambit of his chair. A professor of Spanish, for example, may hold himself bound to instruct the public opinion of his community on Spanish affairs, and even to suggest the adoption of a definite attitude by his fellow-countrymen in relation to such affairs, if they have become the question of the hour, pregnant with issues of peace or war, and if he has a knowledge which has not yet been attained by publicists, journalists, and other such guides of public thought. On the other hand, it is a pity that a professor should become a publicist except in the gravest emergency. It is difficult to be at once a publicist and a scholar ; and a professor is primarily a scholar. Here we touch a fundamental consideration. A professor is a citizen, with the general rights or obligations of a citizen : he is also a member of a profession, with the special obligations of that profession. Herein he is like the doctor or lawyer, who have also their special obligations, as, for example, the obligation of secrecy in regard to the affairs of their clients. The special obligations of the professor, which are contained in the unwritten code of which we have already spoken, are less definite than those of the doctor or lawyer ; but they are there. He has embraced a profession devoted to the dispassionate search for pure truth. He seeks truth for truth's sake by a rigorous method of inquiry. The temper of his mind must be steeled into a resolute disposition to see every side and to weigh every factor. He is training young minds : what he is, and what he does, affects the growth of those minds, just because the attitude, the temper and the method of the teacher are always a suggestive force to the young, and are always, however unconsciously, in virtue of that law of imitation which sways so strongly all our minds, the fountain and source of a like attitude, temper and method among the taught. If there is a discipline which is a special obligation of the soldier, there is also a discipline which is a special obligation of the professor who serves under the banner of truth. To see, and to show to others, the six sides of a square question : to amass every relevant fact, and to leave no fact unverified : to shun the limelight of publicity, because it distorts and is not the clear light of truth : not to lend knowledge to the service of a one-sided cause, or to divulge research in aid of a journalistic ' scoop '—all these are parts of the discipline. At the same time, the professor must be a man, and not an automaton. He may become the latter, if he is purely and solely of the laboratory. Some measure of outside interest and outside work is a condition of vitality and even of balance. Without it he may be anæmically academic, and lose himself in an exaggerated sense of the sovereignty of his subject. F. D. Maurice was not in error when he said of his colleagues that ' their classes in the college, I believe, are infinitely the better for their labours and studies out of it.' [2]

There are certain subjects in which the freedom and the duty of a professor raise specially difficult problems. They are the subjects of history, government and economics—to which we may perhaps add the

[2] *Op. cit.*, ii., p. 85.

subject of modern languages, when the professor of such a subject concerns himself, as it is good that he should, not only with the language and literature but also with the history and contemporary civilisation of the nation with which he is concerned. If the cause of academic freedom was fought in the past on the ecclesiastical field, and in regard to chairs of divinity, it is likely to be fought in the future on the field of politics and economics, and in regard to the chairs which touch those subjects. A professor of such subjects cannot stop short of running into the actualities of the present. If he were required to do so, he would be stopped from reaching what we may almost call the point of fertilisation, where his knowledge touches actual life. I would not say that the history of the past is the guide to the solution of the problems of the present; I would rather say, with Croce, that all history is contemporary history, and that the historian explains what we are by showing to us the living past which makes our present life. Even on that basis, the present is the concern of the historian, as it is also, for that matter, of the teacher of political theory, or of economics, or of modern languages. The teachers of all these subjects are handling and interpreting the present. They move in a region of very special difficulty and very special obligation. They handle the live stuff of which actual political and economic questions, national and international, are made. *Incedunt per ignes.* They may write to the *Times* on current questions, according to our English habit, which has no doubt its American equivalent; they may publish pamphlets and books on current questions; they may even (and this raises desperate difficulties) become parliamentary candidates. I cannot deprecate the trend of these subjects and of their teachers in modern universities towards what I may call actuality. At the same time, I cannot but register the difficulties to which it leads. Public attention may be drawn to a university which has become a live coal, and public criticism may fasten on its burning. What is more, a number of interests may interest themselves in controlling the manner of its burning. Universities are always in need of endowment. A benefactor, or a group of benefactors, may be very ready to found a chair—and that possibly a chair of a certain complexion—in a subject of history, or of politics, or of economics, or of the language, literature and civilisation of a given nation. If the professor is conformable to their expectations, all may be well—from one point of view. If he is not—*surgit quaestio.* But this difficulty belongs rather to the topic of the freedom of the whole academic community, and that belongs to another and later inquiry. Here we are concerned with the freedom of the individual professor. So far as that freedom is concerned, I can only repeat, with some qualification and extension, the conclusions I have already tried to state. My general principle is freedom, uncontrolled by any assumption of responsibility by the university, which is likely to run more danger thereby than can ever be involved in any possible indiscretion which a professor may commit in the use of such freedom. My qualification of that principle is two-fold. In the first place, the freedom of the professor is subject to the discipline of the profession, which commands him to seek the truth, the whole truth, and nothing but the truth. If he cannot submit himself with all his heart to that discipline, he had better quit the profession and become a politician or a journalist. In the second place, the freedom of the professor, while it is not subject to the control of the institution to which he belongs, must

at any rate be qualified by the duties inherent in his membership of that institution. If it gives him freedom, he must not give it obloquy in return. He will be wise, in many cases, to say, and to say very clearly, that he speaks in his own name, as a private citizen, without any warrant from his institution, or any power to bind or conclude his institution in any way by what he says. But I do not think that a professor will ever go far wrong if he submits himself to the discipline of the profession. The great safeguard of true professorial liberty is simply a stern sense of the sanctity of the academic vocation, cherished among all its members, and enforced by all its members through the sanction of disapproval against an erring colleague. What we need is the elaboration by the professors themselves, and the enforcement by the professors themselves, of a code of professional conduct. Here at any rate, without any subscription to the tenets of guild socialism, and without any confession to a creed of the government of the teaching profession by itself, one may see a field for professional self-determination. It is not exactly an easy thing. Some professors, of a conservative cast of mind, will always frown upon their colleagues who are hardier, even when they walk within just limits. Others, of more radical propensities, will always smile upon a bold colleague, even when he has obviously overshot any conceivable mark. But if the thing be difficult, it is none the less needful.

I turn to consider, in conclusion, the broader theme of the freedom of the whole academic community. The mediæval university, as its very name implies, was a free guild of teachers, or sometimes of teachers and scholars. It was not subject to any local authorities (there were none, and anyhow it was not local); it was hardly subject to the State, for the State was a loose federal sort of body, which left all guilds pretty much to their own devices; it *might* be subject to the Pope, because its members were clerks, but it could be turbulently independent even in the face of the Pope. There were benefactors—munificent benefactors—who founded great colleges within the universities; but though they were fond of making statutes for the government of their colleges, they left opinion alone, for the simple reason that there was no need for any sort of control. The curriculum was largely a traditional curriculum in the arts; and if theology was sometimes fertile of heresies, there was, at any rate, only a single Catholic Church, and all men were members of one communion. The modern university is set in a far more tangled web of environment. It is an object of lively interest to the State, which may sometimes exert, or seek to exert, a control of its teachers and its teaching, and may at any rate (I speak of Great Britain) appoint Royal Commissions to inspect and statutory commissions to reform its organisation. Local authorities—a dominion in Canada; a county or city in England—may interest themselves deeply in what they regard as a local university. Benefactions and endowments from private sources may play a large part in determining the extent and the direction of university development. A Labour party may demand that the universities shall undertake extra-mural work among the working classes; an organisation such as our National Union of Teachers may ask that the universities shall make it their policy to accept and train as graduates all the members of the teaching profession in the country. What has become of the free guild of the Middle Ages? And should the free guild of the Middle Ages be our modern ideal?

No modern university can have anything of the freedom of a mediæval university. The mediæval university stood alone ; the modern university is part of a great educational system which embraces the whole community. It cannot control the lower ranges of this system—the elementary and secondary schools—or demand that the work done in those ranges shall be simply preparatory to its own work as conceived and determined by itself ; for a majority of the students in the lower ranges will never come to the universities, and their studies must be organised as ends in themselves, and not as means or propædeutics to work in the university. The university has to adjust itself to the educational system, and not the educational system to itself. That educational system is the result of a social ideal, and that social ideal is in the last resort defined by Parliament. The university is therefore bound to conform to the social ideal adopted by Parliament and expressed in the educational system. It has the one consolation of hoping that by its thinking and teaching it is a great force in forming the social ideal by which it is itself controlled. In English-speaking countries, at any rate, the final authority of the State is not an enemy to the freedom of the university. A much more dangerous enemy is social interests, especially when they are backed by the power of cash. We may not believe in more than $\frac{5}{8}$ of the argument of *The Goose Step,* in which Mr. Upton Sinclair draws his lurid picture of the bogey of social interests. But even with a discount of $\frac{3}{8}$, or more, he is alarming.

It is a saying current in universities—and, I dare say, everywhere else—that finance determines policy. It is certainly true that the methods by which a university secures its revenue cannot be without effect on the freedom with which it develops its policy of education. In no university —not even in Oxford and Cambridge—does the student pay the whole, or anything like the whole, of the cost of his education. In the newer English universities we may say that, on the average, the student provides $\frac{3}{10}$ of the cost of the running of his university. The remaining $\frac{7}{10}$ has to be found from other sources. Before we look at those other sources, we may venture on a general observation. The persons or bodies who provide the required $\frac{7}{10}$ may be inspired by a variety of motives. We may put first the motive of advancing the cause of truth and promoting the higher education of the best minds of the community. But we must allow for the entry of other motives. A university is, we may say, a great pulpit ; and there will also be some who desire to 'tune the pulpits,' and to make the preachers say acceptable things. It is another current saying that those who pay the piper call the tune. We should be shutting our eyes to a genuine danger if we did not admit the possibility of 'tuning.' And if we regard it as an undesirable possibility, we must be ready with suggestions for its avoidance or, at any rate, its diminution.

There are three possible sources of university revenues. One is the fees of students : a second is private benefaction : a third is public assistance, whether from the national or the local authority. It is a desirable thing that universities should continue to draw an income from the fees of their students. It is earned income : it is independent money. It is good both for the university and its student, making the one feel that it earns as well as spends, and the other that he gives as well as receives. It is indeed a pity that any system of fees should exclude a single student

of promise from a university. But a proper system of national and local scholarships (which should include maintenance, where it is necessary, as well as fees) will prevent any such exclusion. Granted, therefore, such a system of scholarships, there seems to be every reason for maintaining university fees which provide from $\frac{3}{10}$ to $\frac{2}{5}$ of the income of a university. They help to give the university self-respect and independence: they may help to give the same qualities to students.

The second source of income, which takes the form of private benefaction, has its fine and attractive side. When one listens, in the bidding prayers of the old English universities, to the names of the benefactors of dead and bygone centuries, one cannot but be proud of a great tradition long and truly maintained. And again, when one thinks of the paucity of private benefaction to universities in England to-day, and contrasts the abounding munificence of many cheerful givers in the United States, one cannot but feel abashed. Yet there is some reason for feeling that, in modern democratic communities, there is a limit to the extent to which private benefaction can safely endow universities. Universities are great public institutions. They belong to the general commonwealth. They cannot be proprietary. They cannot be sectarian. They must be above even the suspicion of belonging to one or other side in our social cleavage. They belong to both. A university which relies to any great extent on private benefaction may tend, however unconsciously, to teach and to preach acceptable things; and that is the greatest offence which it can commit against the spirit of truth. To take benefaction if it comes, but not to go out to seek it; to look even a gift-horse in the mouth with a modest and discreet inquiry; to be sure that no endowment contravenes by one jot or tittle freedom of inquiry or freedom of expression—these are the natural policies of a university which respects its own genius of academic freedom. I would not exaggerate the dangers of private benefaction to universities. Often and often it is the fruit of plain and unconditioned generosity. But I would not be blind to the possible dangers. And it is always possible that private benefactions may have their tacit implications—a form of capitalism; a particular kind of nationalism; some brand of confessionalism—which may make them enemies of academic freedom.

I come, in conclusion, to the third source of university revenue, which is that of public assistance from the local or national authority. If our universities are truly great public institutions, subject (as they are in England) to visitation by the State and to reformation by the State, they must be a charge on the public revenues for that part of their expenditure which they cannot earn by fees from their students or receive in gifts from private endowments. In our English system the aid given to education from public funds (whether the education be elementary, or secondary, or university) is always two-fold. Part comes from the local authority—the county or borough council: part comes from the national exchequer. The two co-operate: they bargain, and often dispute, about their respective shares. Sometimes education suffers from their disputes; but in many ways (and not least in universities) it gains from the presence and joint action of the two authorities. The national authority may stimulate a local authority to increase its contribution; the local authority may attach conditions to its contributions which keep the national authority within due limits of action. There is a certain gain in the system of check

and counter-check between local and national authorities. It is more favourable to universities than a system in which there is only a single public authority. It is sometimes a little of a trouble (and in a moment of irritation one might even describe it as a nuisance) that both authorities are apt to crave information about the same point on different schedules. But the gain is much greater than the loss.

The aid which is given by the national authority to universities in Great Britain is at the present time much greater than that which is given by the local authority.[3] And it is given on a singularly liberal scheme. An annual sum of £1,250,000 is distributed by a Treasury Committee of independent scholars among the universities in the shape of block grants, which each university is free to spend along the lines of its own policy. Only in the sphere of medical education, and in respect of the grants made to medical schools, has any specific educational condition been attached. Here the policy of favouring the system of clinical units has been adopted by the Committee, and that policy has its critics. That, however, is the only action which even smacks of interference. The aid given by local authorities is hardly given on so liberal a scheme. Local authorities are apt to regard universities as their own local institutions which they should control to a greater or less degree; and they sometimes allocate their aid to specific purposes only, or attach very definite conditions to their grants. So long as their grants are definitely less than those of the national authority, and so long as there is the dualism of the local and the national authorities, no serious alarm need be felt. At the same time one cannot but feel that the local authorities are inclined to press too far the idea that 'democratic control' of university education means its control by elected local representatives assembled in county or borough council. We may rejoin that democratic control of a university is control by its own governing body, provided that that body is democratically constituted, and is duly subject in serious matters to public criticism. And the Treasury Committee, which virtually proceeds on that conception, seems closest to genuine democratic principles.

On the whole, there is no serious menace to academic freedom in Great Britain from a system of university finance which relies, as our system does, on a balanced mixture of income from fees, public assistance, and private benefaction, with the balance perhaps inclining more and more to a preponderance of public assistance. Much, however, depends on the dualism of our system of public assistance, and much too on our habit of leaving institutions alone, to go their own way, as far as possible. The present position is very tolerably good, and the general English notion of self-government leaves our universities as free as it is good for them to be. There might conceivably arise a government, strongly wedded to definite principles, which refused to give aid to universities unless those principles were taught, or were not, at any rate, neglected in the instruction given by the universities. An advanced Labour Government, for instance, might possibly take objection to the teaching by a university of what, in its view, were 'capitalistic' economics, and the omission of the economics of Socialism. But the possibility is most exceedingly improbable—unless

[3] In England and Wales, during the academic year 1922-1923, the percentage of the total income of universities due to grants from Parliament was 38·1 : that of total income arising from grants made by local authorities was 14·4.

the professors of economics are exceedingly injudicious. We may safely conceive our universities as already, and likely to be more and more, great public institutions, deriving their income in increasing measure without any diminution of freedom from the State and the local authorities. It is to be hoped that the teachers of our universities will *pari passu* conceive themselves (as I believe they increasingly do) as lovers, seekers and preachers of pure knowledge for its own sake, vowed to no party when they speak from the chair, and rising above party so far as they can in all that they say or do in civic affairs outside.

SECTION M.—AGRICULTURE.

PRESENT-DAY PROBLEMS IN CROP PRODUCTION.

ADDRESS BY

SIR E. JOHN RUSSELL, F.R.S.,

PRESIDENT OF THE SECTION.

The visits of the British Association to Canada have hitherto very appropriately coincided with definite stages in the progress of agricultural science and practice. It was at the Montreal Meeting of 1884 that Lawes and Gilbert presented their well-known paper on the sources of the fertility of Manitoba soils which ended the first great period of the development of agricultural science. This period had lasted eighty years; it had been ushered in with the precise and scientific work of de Saussure published in 1804; its outstanding features had been the foundation of agricultural science by Boussingault in 1834, its enrichment by Liebig's brilliant essay of 1840, and its systematic development by Lawes and Gilbert at Rothamsted from 1843 onwards. The whole purpose of the scientific workers of the period was to feed the plant; in Gilbert's own words the message of the crops on the Rothamsted plots was, 'If you won't feed us we won't grow.' The success of the new science was remarkable; its great triumph was the discovery of artificial fertilisers and their introduction into farming practice, and the workers had the great joy of seeing the crop yields rise considerably as the direct and recognised result of their labours. The problems were largely chemical, and agricultural science was regarded as simply a branch of chemistry. Gilbert's paper in 1884 was read before the Chemical Section, and it presented soil fertility as essentially chemical; a fertile soil, he argued, is one containing much plant food, especially nitrogen; it is one 'which has accumulated within it the residues of ages of natural vegetation, and it becomes infertile as this residue is exhausted.' At the time of the Toronto Meeting in 1897 a new period had begun, quietly and unnoticed, but growth was so rapid that at the Winnipeg Meeting in 1909 the subject had grown right away from chemistry; it had become a definite subsection, and its importance was so widely recognised that a recommendation was passed asking the Council to set it up as a full section, which was subsequently done.

In this second period the purpose was not to feed the crop but to study it; to discover what factors are concerned in the growth of crops and how they operate. This period, which may be called the period of free exploration, since the workers were not usually tied down to any particular technical problem, began almost simultaneously in the United States, in France, and in Germany. As soon as agricultural science was studied in the United States it became evident that the cultivation of the soil was at

least as important as the feeding of the crop. This fact had of course been fully recognised in the English experiments, but the English farmer was so skilled in cultivation that he could be taught but little by science. The early American work as developed by Kedzie at Michigan, King at Wisconsin, Hilgard, and Whitney, was largely physical, and it greatly widened the outlook of agricultural investigators, opening the way to the extensive physical and physico-chemical studies which have now become so characteristic a feature of American work. The French investigators, particularly Schloesing, Muntz, Berthelot, and Déhérain, and the brilliant Russian, Winogradsky, then in Paris, revealed a new world of soil micro-organisms, the wonder and mystery of which appealed to the imagination of the younger workers in a way that none of the older utilitarian work had done. The Germans methodically explored the fields thus opened up; Hellriegel and Wollny accumulated a mass of data as to plant growth and soil changes which still remains of value to the student. These pioneers were succeeded by a host of followers whom it would be impossible to enumerate at length, and from whom it would be invidious to select a few. Moreover, the chemists and physicists of the old school were no longer left in sole possession; van Bemmelen introduced the conception of colloids, and at a later date Mitscherlich, Baule, and others developed the idea of mathematical expressions for the data of agricultural science. Sachs and his pupils in Germany, Déhérain, Maquenne and Demoussy in France, joined up the new science of plant physiology with agricultural science. The plant breeder also came in; Gregor Mendel's work, after lying hidden for forty years, was revealed to the world by Bateson and was at once turned to agricultural use in England by one of Marshall Ward's pupils, R. H. Biffen; and in the United States by Webber and others. The selection method was developed to a high pitch of perfection in Canada by William Saunders, a revered leader in our science, whose dignified presence and kindly words of greeting remain as a vivid recollection of our visit fifteen years ago. His mantle has fallen on his son Charles, who has continued and developed the work.

The result of all this effort has been the accumulation of an enormous mass of information covering a very large part of the field with which agriculture has to deal. It has been essentially a pioneer period, with all the advantages of keen individual interest, controversy, sometimes even of excitement; but also with the disadvantages of a certain lack of perspective, failure to follow up important issues and some narrowness of outlook inevitable when a single individual is working alone at a great subject.

Generalisations that have emerged.

But in spite of these drawbacks several important generalisations have emerged. One of the most pregnant in possibilities for the future is the recognition that the plant is a very plastic organisation and can be modified to a considerable extent within certain limits. Two methods are adopted: breeding, which may be on observational lines or on the Mendelian method of picking out the desired unit characters from plants in which they occur and assembling them in a new plant; and selection, in which a desirable plant is caused to produce seed from which stocks are multiplied. The scientific problems fall within the province of the science of genetics;

the practical significance of the work lies in the fact that it greatly simplifies the agricultural problem by providing plants more or less suitable to the existing natural conditions where otherwise the expert would have the difficult, if not impossible, task of making the conditions suit the available plants. The work has proved extraordinarily fruitful and has given astonishing results even in our own time. It has played no small part in the amazing development of wheat growing in Canada. When the British Association went to Winnipeg in 1909 we were all impressed by the fact that Canada had then passed the 160-million bushel mark in production, but who would have thought that within fourteen years the production would exceed 474 million bushels? Even in England, where wheat has been grown for 2,000 years, and where farmers have a long traditional knowledge of the crop, the new varieties introduced by Biffen have increased the yields and the certainty of yields. The triumphs of Webber and others in the United States, of Nielson Ehle with cereals in Sweden, Jeffreys in standardising the quality of cotton in Egypt, the Howards in producing wheats for India, to mention only a few, are still fresh in our minds. In the first period in the development of agricultural science the honours in the matter of practical applications lay with the chemists for the artificial manures, but in the present period we must admit that they lie with the plant breeders and selectors who, indeed, are only on the threshold of what they may yet accomplish. And this great practical purpose of finding or producing varieties of crops specially suited to local conditions would be further advanced if the work were done in co-operation with plant physiologists who could precisely define the modifications required. Much saving of time and effort could be effected if it were possible to set up some International garden where small quantities of the plant-breeders' productions could be grown, including those which each one has rejected as being unsuitable to his particular requirements. Many of these unwanted outcasts might prove of value in other conditions.

A second generalisation is that the soil is not a fixed, constant thing, but is pulsating with change. It contains a great population of micro-organisms which, among other activities, decompose the dead plant residues, producing nitrates, humic and other substances of great importance in crop production. But the numbers of these organisms fluctuate continually, and the bacteria at least change hourly; the nitrates suffer equally rapid changes in amount. Even the mineral part of the soil is not constant in composition. Modern research work shows that many of the properties determining fertility in soils are due to the soil colloids, and some of the most important are attributable to calcium complexes. These are unstable and are affected by the soil water. If the water is free from salts but contains carbon dioxide, the calcium may be replaced by hydrogen, and an acid soil results; if the water contains sodium chloride, the calcium is replaceable by sodium and the resulting complex may readily give rise to an alkali soil. So far as is known, the changes are governed by the ordinary stoichiometric laws, the equilibrium following the usual course expected when a colloid is concerned. But the important fact emerges that any soil not well supplied with calcium contains within itself the possibility of becoming acid and therefore infertile, or alkaline and probably sterile, according to the nature of the soil water soaking through it. The various biological and chemical changes tend to alter the composition of the soil

solution. Apparently, however, the colloids have a steadying or 'buffering' effect, reducing the degree of acidity caused by the production of acids and absorbing or precipitating various ions that might otherwise cause disturbances.

A third important generalisation that has emerged is that the relations of the plant and the soil are not rigidly fixed but are capable of considerable variation, being profoundly influenced by a third factor, the climate. A soil moderately fertile in one set of conditions may be relatively unproductive in another. This happens repeatedly with soils containing much clay or much coarse sand. In Table I. are given the mechanical analyses of two soils, one of which, the Lias clay from England, is quite unworkable and remains derelict under our conditions of cool temperature and moderate but frequent rainfall, by reason of its high content of clay and fine silt; while the other, which contains even more clay, is capable of carrying good crops of grain and cotton under the hot dry conditions of the Sudan. The Western prairie soil is of similar physical type to that of the English Weald soil, but while the prairie soil under its climatic conditions of warm dry summer and cold dry winter is, and is likely to remain, a fertile wheat producer, the Weald soil under the wetter conditions of England is less fertile. In hot dry conditions the clay is no disadvantage and may even be an advantage, but in wet conditions it becomes a serious drawback; indeed, it might be possible to find some mathematical relationship between rainfall and degree of objectionableness in clay.

TABLE I.

Soils of similar type as regards mechanical analysis, but varying greatly in fertility by reason of climatic differences.

	Rich in finer fractions				Rich in coarser fractions	
	Waste land very difficult of cultivation	Fertile soil, millet & cotton	Poor farm land difficult to cultivate	Good prairie soil, Wheat	Waste land, Norfolk	Market garden, Anglesey
	Lias clay Oxfordshire	Sudan	Weald clay, Kent	Brandon	22 in. rain	35 in. rain
Coarse sand, 2·0 to 0·2 mm.	0·7	7·6*	1·5	2·5	62·4	93·7
Fine sand, 0·2 to 0·04 mm.	2·0	20·9	11·0	15·4	25·7	2·8
Silt, 0·04 to 0·01 mm.	6·4	12·6	19·6	17·7	0·2	0·5
Fine silt, 0·01 to 0·002 mm.	22·0		26·8	16·1	1·8	0·4
Clay (below 0·002 mm.)	41·0	55·9	22·1	29·2	0·6	Nil

* Mainly black nodules of calcium carbonate.

It appears then that if a fertile soil were carried from one country to another its productive power would not necessarily be carried with it. Its fertility is, to a considerable extent, dependent on the fact that it fits in with the climatic factors in producing conditions favourable to good growth of desirable crops.

Complexity of the Problem: Methods of Attack.

The agricultural investigator is thus confronted with three closely interlocking agencies—the plant, the climate, and the soil—each of which is variable within certain limits, and each playing a large part in the crop production which it is his business to study.

Confronted with a problem of this degree of complexity there are two methods of procedure: the empirical method of field observations and experiments, in which there is no pretence of great refinement and no expectation that the same result will ever be obtained twice, it being sufficient if over an average of numerous trials a result is obtained more often than would be expected from the laws of chance; and the scientific method, in which the factors are carefully analysed and their effects studied quantitatively; a synthesis is then attempted, and efforts are made to reconstruct the whole chain of processes and results. The scientific method is, of course, the one to which we are naturally attracted. But common truthfulness compels one to admit that up to the present the greatest advances in the actual production of crops have been effected by the empirical method, and not infrequently by men who are really artists rather than men of science, in that they are guided by some intuitive process which they cannot explain, and that they have the vision of the result before they obtain it, which the scientific man commonly has not.

The best hope for the future lies in the combination of the empirical and the scientific methods. This is steadily being accomplished by the recent strong infusion of science into the art of field experimentation, which has much enhanced the value of the field work and the trustworthiness of its results. Modern methods of replication, such as have been worked out at Rothamsted, and in the United States by Harris of the Carnegie Trust (Cold Spring Harbor), Kiesselbach in Nebraska, Myers and Love of Cornell, and others, constitute a marked improvement in plot technique. And the figures themselves, besides being more accurate, can be made to yield more information than was formerly the case.

Great advances have been made in the methods of analysing the results. The figures are never the same in any two seasons, since the climatic conditions profoundly affect the yields. A few men, like J. H. Gilbert, have the faculty of extracting a great deal of information from a vast table of figures, but in the main even the trained scientific worker can make very little of them. The reason is that he has been brought up to deal with cases where only one factor is varying, while the growth of plants involves the interaction of three variable factors: the plant, the soil, and the climate. It is impossible to apply in the field the ordinary methods of the scientific investigator where single factors alone are studied; very different methods are needed, adapted to the case where several factors vary simultaneously.

Fortunately for agricultural science, statisticians have in recent years worked out methods of this kind, and these are being modified and developed by R. A. Fisher and Miss Mackenzie for application to the Rothamsted field data. It so happens that this material is very suitable for the purpose, since a large number of the field experiments have been repeated every year for seventy or eighty years on the same crop and on the same piece of land, using the same methods; the field workers also remain the same for many years, the changes being rare and without break in continuity.

Although the statistical investigation is only recently begun, mathematical expression has already been given to the relationship between rainfall and yield of wheat and barley under different fertiliser treatments, and precision has been given to some of the ideas that have hitherto been only general impressions. If on an average of years a farmer is liable to a certain distribution of rainfall, it is becoming possible to advise as to fertiliser treatment which enables the plant to make the best of this rainfall.

Unfortunately, few other Experimental Stations possess such complete masses of data as Rothamsted. Methods are now being devised, however, both by Fisher and by the able English investigator who modestly conceals his identity under the pseudonym 'Student,' for the study of smaller numbers of data, and it is hoped that these or others equally effective will be applied to the results of field experiments accumulated at various Experimental Stations throughout the world. A massed attack by a competent band of statisticians on the whole of the data of the best Experimental Stations, dealing with yields of crops under different conditions of nutrient supply, temperature, rainfall and other factors that go to make up the aggregate called season, would yield information of extraordinary value.

Investigations of this kind, however, are necessarily slow, and they do not themselves afford complete information; their value lies in the fact that they reduce a very complex problem to a set of single-factor problems of the type with which the scientific investigator is already familiar. In the meantime, while this work is proceeding, much is being done by observational methods. At Rothamsted the field plots are under continual observation by a group of three workers, a physiologist, an ecologist, and an agriculturist, who study such factors as rate or habit of growth, earliness of starting or maturing, degree of resistance to insect or fungus attack; their observations are fully recorded and brought before the chemical, physical and botanical departments at regular and frequent intervals. Certain of the experiments are repeated at other centres on closely similar lines for purposes of comparison. In consequence our old field plots which have been studied for the past eighty years by Lawes, Gilbert, Warington, and Hall, and might have been supposed to have no further tales to tell, are found to be still yielding results of great interest in agricultural science and practice.

The Results Obtained: Alterations in the Plant.

We shall begin with the results obtained by effecting alterations in the plant. Reference has already been made to the changes brought about by the plant breeder, and we need not stop to argue whether the great improvements in crops made in pre-Mendelian days by the Suttons and Findlay in potatoes, by Chevalier in barley, by the Gartons in oats, Vilmorin in sugar beet, and others, should be labelled empirical or scientific. There are certain other changes in plants, however, of a purely temporary nature, which have been induced by changes in conditions. It is a commonplace among farmers that certain soil conditions influence not only the yield but also the quality of crops. The leaf and root are more easily affected than the seed. The case of mangolds has been investigated at Rothamsted; the sugar content of the root, an important factor in determining feeding value, was increased by increasing the supply of potassium to the crop. Middleton at Cockle Park showed that grass increased in feeding value—

quite apart from any increase in quantity—when treated with phosphates. Potatoes are considerably influenced by manuring ; increasing the supply of potassium influences the composition of the tubers and also that much more impalpable quality—the cook's estimate of the value of the potato ; while we have found at Rothamsted that a high-class cook discriminated between potatoes fertilised with sulphate of potash and those fertilised with muriate of potash, giving preference to the former.

Grain is more difficult to alter by changes in environmental conditions ; indeed, it appears that the plant tends to produce seed of substantially the same composition whatever its treatment—with the important exception of variation in moisture supply. Mr. Shutt has explored the possibilities of altering the character of the wheat grain by varying the soil conditions, and finds that increases in soil moisture decrease the nitrogen in the grain. Similar results have been obtained in the United States.

On the other hand, in England the reverse seems to hold, at any rate for barley. This crop is being fully investigated at the present time under the Research Scheme of the Institute of Brewing, because of its importance in the preparation of what is still Britain's national beverage. Increased moisture supply increases the percentage of nitrogen in the grain, and so also does increased nitrogen supply, though to a much less extent ; on the other hand, both potassic and phosphatic fertilisers may decrease the percentage of nitrogen, though they do not always do so ; the laws regulating their action are unknown to us.

The practical importance of these problems of regulating the composition of the plant lies in the fact that the farmer can control his fertiliser supply, and also to some extent his moisture supply, so that it lies within his power to effect some change should he wish to do so.

The following are the nitrogen contents and the valuations of barley grown in the same season from the same lot of seed on farms only a few miles apart :—

Effect of Moisture.

	Drier soil	Moist land
Nitrogen per cent. in grain	1·44	1·80
Valuation per quarter of 448 lb. ..	52*s*. 5*d*.	41*s*. 6*d*.

Effect of Nutrients.

	No nitrogenous manure	Nitrogenous manure
Nitrogen per cent. in grain	1·379	1·464
Valuation per quarter of 448 lb. ..	53*s*.	52*s*.

At present we know but little about the matter and we are not in a position to advise the farmer as to how he may use these facts to the full advantage. The complete study of the problem necessitates the co-operation of a plant physiologist.

There is another direction also in which alterations in the plant would be of great value if only we knew with certainty how to bring them about.

In agricultural science one sometimes thinks only of the crop and the factors that affect its growth. But in agricultural practice there is often another partner in the concern : a pest or parasite causing disease. The amount of damage done by pests and diseases to agricultural crops is

astounding; in Britain it is probably at least 10 per cent. of the total value of the crops and the loss is probably some 12,000,000*l*. sterling per annum; in some countries it is considerably more. Indeed, the number of insect pests and of harmful fungi and bacteria that skilled entomologists and mycologists have found in our fields might almost lead us to despair of ever raising a single crop, but fortunately the young plant, like the human child, grows up in spite of the vast number of possible deaths. The saving fact seems to be that the pest does harm only when three sets of conditions happen to occur together: the pest must be present in the attacking state; the plant must be in a sufficiently receptive state; and the conditions must be favourable to the development of the pest. It is because this favourable conjunction of conditions comes but rarely that crops manage to survive. And this gives us the key to control if only we knew how to use it. Complete control of any of these three conditions would end all plant diseases. Unfortunately, control is never complete even in glasshouse culture, still less out of doors. But even partial control would be very helpful. All these pests go through life cycles, which are being studied in great detail all over the world, and especially in the United States. Somewhere there occurs a stage which is weaker or more easily controlled than others, and the pest would become harmless if the chain could be broken here or if the cycle could be sufficiently retarded to give the plant a chance of passing the susceptible stage before it is attacked.

The plants themselves, as we have just seen, are in some degree under control, and if they could be pushed through the susceptible stages before the pest was ready they would escape attack. Barley in England is sometimes considerably injured by the gout fly (*Chlorops tæniopus*). The larvæ emerge in spring from the eggs laid on the leaves and invariably crawl downwards, entering the young ear if, as usually happens, it still remains ensheathed in leaves. J. G. H. Frew, at Rothamsted, has shown that early sowing and suitable manuring cause the ear to grow quickly above the track of the larvæ, and thus to escape injury. E. A. Andrews, in India, has found that tea bushes well supplied with potassic fertiliser escape attack from the mosquito bug (*Helopeltis*) for the rest of the season, apparently because bushes so treated become unsuitable as food to the pest. And further, the conditions are alterable. H. H. King, in the Sudan, has effected some degree of control of the cotton thrips (*Heliothrips indicus*) by giving the plant protection against the drying North wind and so maintaining a rather more humid atmosphere—a condition in which the plant flourishes more than the pest. Tomatoes in England suffered greatly from *Verticillium* wilt till it was found that a small alteration of temperature threw the attack out of joint. They are also much affected by stripe disease (*B. lathyri*), but they become more resistant when the supply of potash is increased relative to the nitrogen. It has recently been maintained, though the proof is not yet sufficient, that an altered method of cultivating wheat in England will afford a good protection against bunt. These cultural methods of dealing with plant diseases and pests offer great possibilities, and a close study jointly by plant physiologists and pathologists of the responses of the plant to its surroundings, and the relationships between the physiological conditions of the plant and the attacks of its various parasites, would undoubtedly yield results of great value for the control of plant diseases. Again, however, the plant breeder can save a world of trouble

by producing a variety resistant to the disease; or there may fortunately be found an immune plant from which stocks can be had, as in the case of the potatoes found by Mr. Gough to be immune from the terrible wart disease.

Control of Environmental Factors.

It thus appears that, if only plant breeders and plant physiologists could learn to alter existing plants or to build up new plants in such a way that they should be well adapted to existing soil and climate conditions, and not adapted to receive disease organisms at the time the organisms are ready to come—if only they could do this all agricultural land would become fertile and plant diseases and pests would become ineffective: at any rate until the pests adapted themselves to the new plants. Although no one can set limits to the possibilities of plant breeding and plant physiology, we cannot assume that we are anywhere near this desirable achievement or that we are likely to be in our time. There will always remain the necessity for altering the environmental conditions to bring them closer to the optimum conditions for the growth of the plant. No attempt is yet made in the field to control two of the most important of the factors: the light and the temperature, though it is being tried experimentally. There is a great field for future workers here; at present plants utilise only a fraction of the radiant energy they receive. At Rothamsted attempts have been made by F. G. Gregory to measure this fraction; the difficulties are considerable, but the evidence shows that our most efficient plants lag far behind our worst motor-cars when regarded as energy transformers for human purposes. One hundred years ago the efficiency of an engine as transformer of energy was about 2 per cent.; now, as a result of scientific developments, it is more than 30 per cent. To-day the efficiency of the best field crops in England as transformers of the sun's energy is about 1 per cent.[1]: can we hope for a similar development in the next hundred years? If such an increase could be obtained an ordinary crop of wheat would be about 400 bushels per acre, and farmers would feel sorry for themselves if they obtained only 200 bushels. But we are only at the beginning of the subject. Increases in plant growth amounting to some 20 or 25 per cent. have been obtained by V. H. Blackman in England under the influence of the high-tension electric discharge, which presumably acts by increasing in some way the efficiency of the plant as an energy transformer. Possibly other ways could be found. It needs only a small change in efficiency to produce a large increase in yield. Much could be learned from a study of the mass of data which could be accumulated if agricultural investigators would express their results in energy units as well as in crop yields as at present.

Interesting results may be expected from the attempts now being made in glasshouse culture both in Germany and at Cheshunt to increase the rate of plant growth by increasing the concentration of the carbon dioxide in the atmosphere.

Control of the Soil Factors.

The soil factors lend themselves more readily to control and much has been already achieved. Water supply was one of the first to be dealt

[1] The remaining energy being largely used up in transpiration. This figure refers to the total radiation received by the leaf, and not to the fraction received by the chloroplast surface. For this latter the value is much higher.

with. Civilisation arose in the dry regions of the earth, and as far back as 5,000 years ago irrigation was so advanced as a practical method that it came into the ordinances drawn up by the great Babylonian king Hammurabi. The chief problems at the present time are to discover effective means of economising water and to ascertain, and if possible control, the relationships between the soil, the water, and the dissolved substances in the water. Economical use of water is necessary because it allows larger areas to be irrigated, and because water beyond a certain amount injures the soil and asphyxiates the plant roots. This part of the problem is largely one of engineering and police control. The more serious problem, perhaps the most serious confronting agricultural science to-day, is that presented by the soluble matter in the water and the soil. The terrible spectre of alkali looms ahead of every irrigation project; it may be kept under control for a longer or shorter time or it may completely wreck the scheme. Instances could be multiplied of schemes started with great expectations of results yet yielding only disappointment and loss. A volume could be filled with the tragedies of the alkali problem. Neutral salts, particularly sodium sulphate, are not harmful to plants unless their concentration exceeds a certain critical value; indeed, some of the heavy soils in dry countries, as in Egypt and the Sudan, become unworkable if washed with pure water; they remain flocculated only because some soluble salts are present. Chlorides beyond a critical concentration are more harmful to the plant, but sodium carbonate is deadly, and there is no certain way at present of overcoming its effects.

The empirical method has apparently gone as far as it can, and nothing more can be expected until some fresh opening is discovered by scientific workers.

Almost equally important is the more efficient utilisation of water in districts where the rainfall is sufficiently high to obviate the need for irrigation, but insufficient to allow of any wastage of water. The practical work of the Utah agriculturists as exemplified by Widstoe, and the laboratory results of Keen at Rothamsted, all indicate that something can be done. It is legitimate to hope that the next great advance will come from Canada, where in the West there are admirable opportunities for studying the problem.

Inseparably bound up with water supply are the questions of cultivation and of drainage, which affect not only the water but the air supply to the roots. This former subject is now attracting considerable attention: the great need is to discover means for expressing cultivation in exact physical and engineering units. The measurements of Keen and Haines at Rothamsted, and the chemical work of A. F. Joseph, N. Comber, and others on clay, and of Odén, Page, and others on humus, indicate the possibility of finding exact expressions and of effecting co-operation with the workers in the new fields of agricultural engineering.

Another soil factor which readily lends itself to some degree of control is the amount of plant nutrients present. The possibility of increasing this by means of manure has been so frequently explored in field trials that it has sometimes been regarded as almost a completed story; indeed, Rothamsted tradition affirms that Lawes himself once gave orders to have the Broadbalk field experiments discontinued because they had nothing further to tell; it was only the earnest persuasion of Gilbert that caused

him to countermand the order. So far from the subject being exhausted, it still bristles with problems. The new nitrogenous fertilisers, resulting from war-time activities in nitrogen fixation; the need for reducing the cost of superphosphate; the change in character of basic slag; and the Alsatian development in potash production are producing changes in the fertiliser industry the full effects of which are not easy to foresee. Economic pressure is driving the farmer to derive the maximum benefit from his expenditure on fertilisers, lime, farmyard manure and other ameliorating agents, and is compelling a more careful study of possibilities hitherto disregarded, such as the use of magnesium salts, silicates, and sulphur as fertilisers, and, above all, a much more precise diagnosis of soil deficiencies than was thought necessary in pre-war days.

But there are more fundamental problems awaiting solution. It is by no means certain that we know even yet all the plant nutrients. The list compiled by Sachs many years ago includes all needed in relatively large amounts, but Gabriel Bertrand has shown that it is not complete and that certain substances—he studied especially manganese—are essential, although only in very small amounts. Miss Katherine Warington, working with Dr. Brenchley at Rothamsted, has shown that leguminous plants fail to develop in the so-called complete culture solution unless a trace of boric acid is added. Mazé has indicated other elements needed in small amounts.

Another problem needing elucidation is the relationship between the quantity of nutrients supplied and the amount of dry matter produced. Is dry matter production simply proportional to nutrient supply, as Liebig argued, with the tailing off beyond a certain point, as demonstrated by Lawes and Gilbert, or is it always less than this, as indicated by Mitscherlich's logarithmic curve, or is the relationship expressed by one of the more complex sigmoid curves as there is some reason to suppose? We do not know; and the problem is by no means simple, yet it governs the 'diminishing returns' about which farmers now hear so much. Again, very little is known of the relationship between nutrition and period of growth. One and the same quantity of a nitrogenous fertiliser, for example, may have very different effects on the plant according as it is given early or late in life; not only is there a difference in quantity of growth, but also in the character of the growth. Late dressings cause the characteristic dark-green colour to appear late in the season, and thus affect the liability to fungoid diseases; they increase the percentage of nitrogen in the grain and they may give larger increases of crop than early dressings.

Investigations are needed to find the best methods of increasing the supply of organic matter in the soil and its value for the different crops in the rotation.

All these problems will sooner or later find some solution. But there remains a greater problem of more importance than any of them: the linking-up of plant nutrition studies with those of the soil solution. As our cousins in the United States were the first to emphasise, the fundamental agent in the nutrition of the plant is the soil solution, and they have made a remarkable series of investigations into what appeared at one time a hopeless proposition—the physico-chemical interactions between the soil and the soil water. Whitney and Cameron began the work, and it has gone on with much controversy—as important scientific investigations

always do—and it is now being attacked with much vigour by some of the younger scientific workers, particularly in the Californian school: Burd, Hoagland, Kelley, Lipman, Stewart, Sharp, and others. There is also some valuable work by Gola and other Italians. The natural soil solution is not always the best for the growth of plants. It is reasonable to suppose that the most efficient method of using fertilisers would be for making up the soil solution to the optimum composition and concentration for each stage of the growth of the crop. Unfortunately, this cannot yet be done. The added fertiliser does not simply increase the concentration of the soil solution to the precise extent that might be expected; there are interactions, absorptions, and base exchanges of the kind studied first by Way, much later by van Bemmelen and by Gedroiz, and more recently by Hissink and by Wiegner. Further, the plant relationships are not constant; there is apparently—though this is not certain—more response to certain nutrients at one time of its life than at another. A great advance in crop production may be expected when the soil chemists have discovered the laws governing the soil solution, when the plant physiologists can give definite expression to the plant's response to nutrients, and when someone is able to put these results together and show how to alter the soil solution so that it may produce the maximum effect on the plant at the particular time. The new soil chemistry will yet have its triumphs.

The Soil Micro-organisms: Can they be Controlled?

It is now more than forty years since the discovery of the great importance of micro-organisms in determining soil fertility. Practical applications necessarily lag far behind; but already three have been made, each of which opens out great possibilities for the future. The long-standing problem of inoculation of leguminous crops with their appropriate organisms has already been solved in one or two of its simple cases, chiefly lucerne on new land, and the new process has helped in the remarkable extension of the lucerne crop in the United States and in Denmark. We believe at Rothamsted that the more difficult English problem is now solved also. Interesting possibilities are opened up by the observation that a preliminary crop of Bokhara clover seems to facilitate the growth of the lucerne.

The organisms effecting decomposition are now coming under control, and are being made to convert straw into farmyard manure (or a material very much like it) without the use of a single farm animal. The process was worked out at Rothamsted, and is being developed by the Adco Syndicate, who are now operating it on a large scale and are already successfully converting some thousands of tons of straw annually into good manure.

The third direction in which control of the soil organisms is being attempted is by partial sterilisation. This process is much used in the glasshouse industry in England, and it has led to considerable increases in crop yields. The older method was to use heat as the partial sterilising agent, and this still remains the most effective, but owing to its costliness efforts have been made to replace it by chemicals. Considerable success has been attained; we have now found a number of substances which seem promising. Some of these are by-products of coal industries; others, such as chlor- and nitro-derivatives of benzene or cresol, are producible as crude intermediates in the dye industry.

The Need for Fuller Co-operation.

Looking back over the list of problems it will be seen that they are all too complex to be completely solved by any single worker. Problems of crop production need the co-operation of agriculturists, plant physiologists, soil investigators, and statisticians. Even plant breeding necessitates the help of a physiologist who can specify just what the breeder should aim at producing. And this gives the key-note to the period of agricultural science on which we have now entered—it is becoming more and more a period of co-operation between men viewing the problem from different points of view. Good individual work will of course always continue to be done, but the future will undoubtedly see a great expansion of team work such as has already led to important results in medical research, and such as we know from our experience at Rothamsted is capable of giving admirable results in agricultural science.

The team work should not be confined to individuals working at the same institution. The world would gain greatly if co-operation such as now exists between the Imperial College Botany School and Rothamsted could be effected between other great institutions devoted to agricultural science in the various countries of the world. To take only one illustration: how much could be accomplished in the study of the very difficult alkali problem if it were possible to organise a team representing such great agricultural stations as, for instance, California and Utah, the Departments of Agriculture of India and other of the great Dominions affected, Rothamsted, Hissink's school, with power to lay down experiments anywhere and money to carry them out. And if extended co-operation of this kind should prove impossible of attainment, much could be done by fostering co-operation between the Agricultural Institutions of the Empire. There are certain great problems which are common to large parts of the Empire where the experience of one part would be of great value to the rest. The institutions in Britain, for example, have experience of problems connected with land long since settled and brought into cultivation, where men must produce 40 or more bushels per acre of wheat and 6 to 10 tons per acre of potatoes to make these crops pay, and where animal husbandry must be run on sound and economic lines. Canada has an unrivalled experience with wheat, and in the Western provinces has a magnificent chance for studying one of the most important problems of the day—the water supply to the crop. Australia, New Zealand, South Africa, East, West, and Tropical Africa, India, the West Indies—to mention only a few in the great family that forms the British Empire—all have their special lines in agricultural development; each has some achievement that can be shown with pride and in the certainty that its study will benefit others. The Empire has already its Conference of Premiers, why should it not have its conference for agricultural science and practice?

With fuller co-operation both of men and of institutions we could do much to overcome the present difficulty in regard to utilising the information we already possess. In the last thirty years an immense stock of knowledge has been obtained as to soils and crops—knowledge that ought to be of supreme value in interpreting the facts of Nature as shown in the field. It is stored in great numbers of volumes which line the shelves of our libraries, and there much of it rests undisturbed in dignified oblivion. In the main it consists of single threads followed out more or less carefully;

only rarely does some more gifted worker show something of the great pattern which the threads compose. But even the most gifted can see but little of the design ; the best hope of seeing more is to induce people to work in groups of two or three, each trained in a different school and therefore looking at the problem from a different point ; each seeing something hidden from the rest. Unlike art, science lends itself to this kind of team work ; art is purely an individual interpretation of Nature, while science aims at a faithful description of Nature, all humanistic interpretation being eliminated. There is certainly sufficient good-will among the leaders of agricultural science to justify the hope of co-operation ; there are probably in existence foundations which would furnish the financial aid.

And that leads to my last point. What is the purpose of it all ? Team work, co-operation, the great expenditure of time and money now being incurred in agricultural science and experiment—these are justified only if the end is worthy of the effort. The nineteenth century took the view that agricultural science was justified only in so far as it was useful. That view we now believe to be too narrow. The practical purpose is of course essential; the station must help the farmer in his daily difficulties—which again necessitates co-operation, this time between the practical grower and the scientific worker. But history has shown that institutions and investigators that tie themselves down to purely practical problems do not get very far ; all experience proves that the safest way of making advances, even for purely practical purposes, is to leave the investigator unfettered. Our declared aim at Rothamsted is ' to discover the principles underlying the great facts of agriculture and to put the knowledge thus gained into a form in which it can be used by teachers, experts, and farmers for the upraising of country life and the improvement of the standard of farming.'

This wider purpose gives the investigator full latitude, and it justifies an investigation whether the results will be immediately useful or not—so long as they are trustworthy. For the upraising of country life necessitates a higher standard of education for the countryman ; and education based on the wonderful book of Nature which lies open for all to read if they but could. How many farmers know anything about the remarkable structure of the soil they till, of its fascinating history, of the teeming population of living organisms that dwell in its dark recesses ; of the wonderful wheel of life in which the plant takes up simple substances and in some mysterious way fashions them into foods for men and animals and packs them with energy drawn out of the sunlight—energy which enables us to move and work, to drive engines, motor-cars, and all the other complex agencies of modern civilisation ? No one knows much of these things ; but if we knew more, and could tell it as it deserves to be told, we should have a story that would make the wildest romance of human imagination seem dull by comparison and would dispel for ever the illusion that the country is a dull place to live in. Agricultural science must be judged not only by its material achievements, but also by its success in revealing to the countryman something of the wonder and the mystery of the great open spaces in which he dwells.

REPORTS ON THE STATE OF SCIENCE,

ETC.

Seismological Investigations.—*Twenty-ninth Report of Committee* (Professor H. H. TURNER, *Chairman*; Mr. J. J. SHAW, *Secretary*; Mr. C. VERNON BOYS, Dr. J. E. CROMBIE, Dr. C. DAVISON, Sir F. W. DYSON, Sir R. T. GLAZEBROOK, Dr. HAROLD JEFFREYS, Professor H. LAMB, Sir J. LARMOR, Dr. A. CRICHTON MITCHELL, Professors A. E. H. LOVE, H. M. MACDONALD, *and* H. C. PLUMMER, Mr. W. E. PLUMMER, Professor R. A. SAMPSON, Sir A. SCHUSTER, Sir NAPIER SHAW, *and* Dr. G. T. WALKER). [*Drawn up by the Chairman except where otherwise mentioned.*]

General.

THERE is no modification to report in the general situation at Oxford. The tenant of the house purchased by Dr. Crombie's benefaction shows no disposition to move; but the work has been carried on in the 'Students' Observatory' without serious difficulty.

The salary for Mr. J. S. Hughes, provided for the first year entirely by the generosity of Dr. Crombie, has for the second year been provided half by Dr. Crombie and half by the Board of Scientific and Industrial Research. Mr. Hughes has taken over the work of determining epicentres and times, under the general supervision of Professor Turner, and by this welcome addition to our resources arrears are being steadily reduced, as mentioned below.

International.

Seismology has sustained further severe losses by the deaths of Dr. Otto Klotz of Ottawa and Professor Omori of Tokyo. Our deep sympathies are extended to Japan, not only for this personal loss, but on account of the terrible calamity which befell Tokyo and Yokohama in the devastating earthquake of September 1.

There is to be a meeting of the International Union for Geodesy and Geophysics in Madrid in October next. Professor H. H. Turner and Mr. J. J. Shaw have been in nominated by our National Committee as delegates for Seismology.

Instrumental.

Nothing has yet been heard of the seismograph taken to Christmas Island by the Eclipse observers in 1922. Writing under date June 4, Mr. H. S. Jones, now H.M. Astronomer at the Cape, promises to write again to Christmas Island on the subject.

Mr. J. J. Shaw has despatched two of his seismographs to Entebbe in Uganda, and one to Fordham University, New York. These were independently purchased, but are mentioned to show the expanding distribution of machines of the type approved by the Committee.

Another instrument has been prepared by him for exhibition at Wembley, whither some maps showing the distribution of epicentres and of observing stations, and a set of the publications, are also being sent.

The performance of the Milne-Shaw seismograph has, moreover, been tested by Professor Rothé on the experimental table at Strasbourg with very satisfactory results. The curve representing the motion of the table is almost identical with that shown by the seismograph.

[*The remainder of this section is due to Mr. Shaw.*]

The movements of the table are produced by an electrically driven cam, the amplitude and periodicity of which can be changed at will. Its motion is recorded mechanically on smoked paper. The seismograph is placed upon the table, but records photographically. Both curves are timed by the same electric circuit. The apparatus was tested with both simple and complex periods and in each case faithful records were obtained.

Fig. 1 illustrates curves where the periods of the table and pendulum were alike (a condition when distortion due to synchronism is most likely to develop). Curve A shows a table movement of 0·13 mm. magnified 109 times. B is the corresponding seismogram, in which, by the Galitzin formulas, the magnification should be 187.

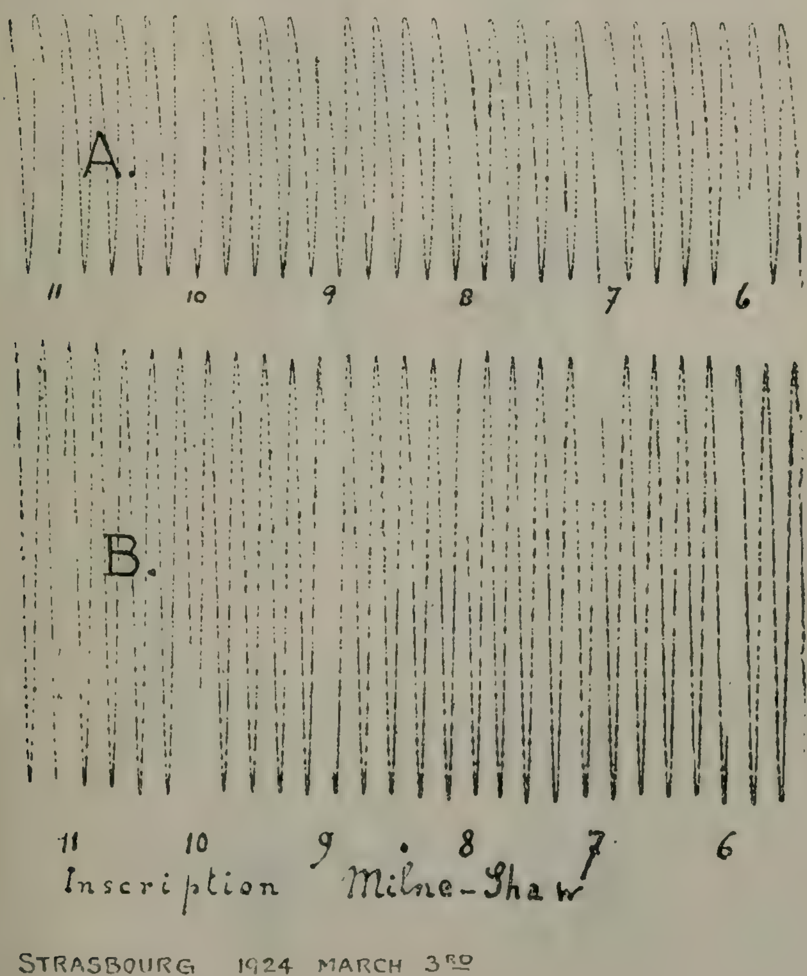


Fig. 1.

Measurement of the curve shows magnifications ranging between 181 and 187, illustrating not only the fidelity of the seismogram but also the close agreement between present practice and the formula in use.

While referring to instrumental points of this kind, it is interesting to observe how two machines standardised to similar constants and fully damped do produce similar

records. The two seismograms reproduced side by side in fig. 2 are of the same earthquake taken upon different machines operating in the same azimuth and on the same time circuit, but in separate buildings 60 feet apart. The machines were on test at West Bromwich, their standardising being incomplete. The respective nominal magnifications were 141 and 161, which accounts for the slight difference in amplitude. The amplitudes of the large wave after the 26th minute are in the ratio of 141 to 163.

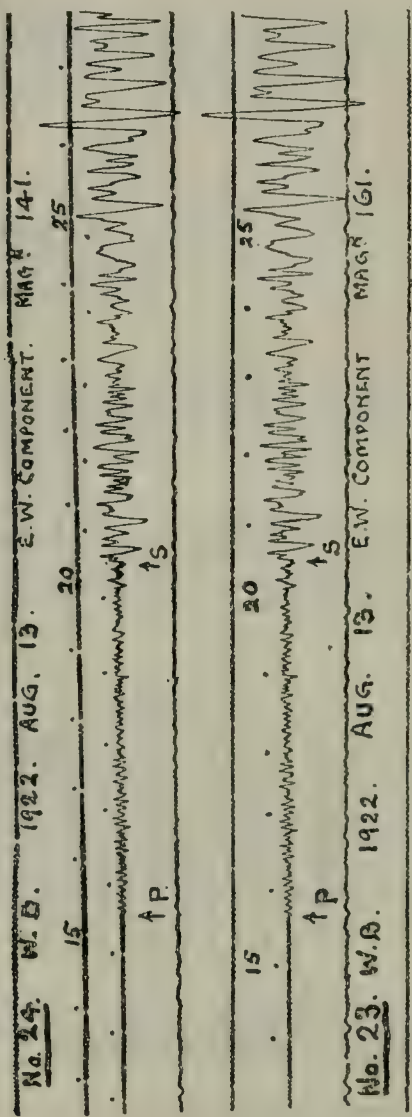


Fig. 2.

Bulletins and Tables.

The 'International Seismological Summaries' for July to September 1918 and October to December 1918, for January to March 1919, April to June 1919, and July to September 1919, have been printed and distributed. October to December 1919 is in the press; and for the year 1920, January to March is being finally checked for press, and the first draft is made for the months April to August. This steady progress has been rendered possible by the services of Mr. J. S. Hughes.

Depth of Focus.

A list of cases of abnormal focus up to May 1918 was given in the last report. To these may now be added

Group I. (High Focus).

		d.	h.	m.	s.	°	°	Depth	[P] s.
1918	July	8	10	22	7	26·5 N	91·2 E	—·010	+ 6
1918	Sept.	7	17	15	51				
1918	Sept.	8	0	9	30	46·5 N	151·4 E	—·030	+20
1918	Sept.	11	4	6	5				
1919	April	30	7	16	55	19·5 S	173·0 W	—·015	+ 7
1919	May	6	19	40	45	6·0 S	153·0 E	—·030	+36
1919	May	29	10	59	45	31·5 N	100·5 E	—·020	?
1919	Oct.	12	21	48	15	2·0 S	102·5 E	—·020	+12

(Group II. represents the vast majority of earthquakes at normal depth.)

Group III. (Deep Focus).

		d.	h.	m.	s.	°	°	Depth	[P] s.
1918	Nov.	18	18	41	45	8·0 S	127·5 E	+·030	—25
1918	Nov.	23	22	57	45				
1918	Dec.	14	18	39	15	13·0 S	166·8 E	+·030	—25
1918	Dec.	25	10	21	10	7·0 S	153·0 E	+·070	?
1919	Jan.	1	3	0	0	20·5 S	178·5 W	+·030	—30
1919	Mar.	1	13	36	0	9·0 N	141·0 E	+·030	—18
1919	Mar.	2	3	26	40				
1919	Mar.	2	11	45	10	43·7 S	77·0 W	+·020	— 9
1919	Mar.	9	3	16	45				
1919	Mar.	13	14	16	55	8·5 S	124·5 E	(suggested)	—65
1919	Mar.	16	7	33	10	9·5 N	127·0 E	+·015	?
1919	Mar.	16	15	3	0				
1919	April	17	20	53	5	14·5 N	91·0 W	+·010	?
1919	May	3	0	51	55	40·7 N	145·8 E	+·005	— 7
1919	June	1	6	51	13	25·7 N	124·8 E	+·040	—15
1919	Aug.	18	16	55	25	17·0 S	177·5 W	+·050	—34
1919	Aug.	18	20	52	0				
1919	Aug.	31	17	20	34	15·7 S	167·3 E	+·015	—13
1919	Oct.	27	3	40	48	16·0 S	69·5 W	+·040	—44
1919	Nov.	6	7	13	10	13·5 N	59·0 W	+·010	?
1919	Nov.	20	14	11	38	13·0 S	166·8 E	+·040	—29

In some of these cases the rule of insisting on the existence of evidence from *both* epicentral and anticentral stations has been relaxed; for with accumulating evidence of variation in depth, it is natural to accept plain indications without too exacting conditions. But generally the double evidence is available.

With regard to the position tentatively occupied in the last report, that there are three definite surfaces at which shocks occur, it will be seen that there are seven entries out of fifteen with depth either +·030 or +·040; there are two greater (+·050 and +·070), six less (+·020, +·015, +·015, +·010, +·010, and +·005), and one uncertain: all these *below* the normal, with a mean value near +·030. On the side *above* the normal the mean value — ·025 is not far from any of the entries. The difference ·055 between these extremes is comparable with Galitzin's ·060 between his uppermost and lowest surfaces, so that the hypothesis of identity may reasonably be retained for trial, though the three critical depths are clearly regions of maximum occurrence rather than definite surfaces.

Periodicity.

Further study of the 21-minute periodicity led, by a devious route, to the conclusion that it is controlled by the Moon, and is of the nature of a tidal effect. The re-examination of the material (especially the series of 6,000 Jamaica earthquakes) from this point of view is not yet complete, and has involved more than one change of hypothesis in detail. The general idea that the meridian passage of the Moon on each day should be taken as the reference point, and that there are an exact number

of periods in each lunar day, has, from the first, given results strongly supporting the idea of lunar action. But the exact number of periods was at first wrongly assessed as 71, then as 70, and ultimately appears to be 68. In view of these successive changes, it is clearly desirable to obtain complete confirmation before publishing the details. It will easily be seen that each modification of the hypothesis in dealing with such a large mass of material has involved a good deal of work.

Local Variations of the Earth's Gravitational Field.—*Report of Committee* (Col. H. G. LYONS, *Chairman*; Capt. H. SHAW, *Secretary*; Professor C. VERNON BOYS, Dr. C. CHREE, Col. Sir G. P. LENOX-CONYNGHAM, Dr. J. W. EVANS, Mr. E. LANCASTER JONES; the DIRECTOR-GENERAL, *Ordnance Survey*; the DIRECTOR, *Geological Survey of Great Britain*).

DURING the year investigations have been conducted with the Eötvös Torsion Balance, both in the laboratory and in the field. A new model of this instrument manufactured by a British firm has been tested, and compared with the instrument belonging to the Science Museum. These tests confirmed the superiority of the double beam instrument over the smaller type having only a single beam, and established the efficiency of the new instrument.

A collapsible double-walled tent to protect the instrument during observations in the field has been designed and constructed in the workshops of the Science Museum. On completion of this, both the balances were tested in the open air near the laboratory. The readings were found to remain comparatively constant during the night, but were subject to considerable variations during the day, especially just after sunrise, and also at times when the temperature increased rapidly. An attempt to discriminate between the effects due to temperature fluctuations and solar radiation led to an investigation in the laboratory, in which the instruments were subjected to measured temperature changes in darkness. It was found that rapid fluctuations of temperature have a serious disturbing effect upon the stability of the balance beams. As an opportunity for a field test of the instruments occurred during the temperature tests, these latter were suspended, and will be continued in the near future.

Field Tests.—At the request of the Shropshire Mines, Ltd., the two balances were transported by road to the Company's mining areas near Shrewsbury. Observations were made with the British instrument at seven stations in a region below which a mineral lode was being worked at a depth of 400 ft. From the dip and direction of this lode it was expected to come near the surface somewhere in the area surveyed. The results of the seven observations showed that a mass of heavy mineral existed below the area. The position, extent, and depth of this deposit were roughly determined, and it is understood that steps are being taken by the Company to verify these conclusions by drilling.

Both instruments were then moved to another area, well beyond the actual mine workings, and observations were made with the object of determining whether mineral lodes existed in this area. In this region observations were taken at twenty-three stations with a few repetitions, two stations being occupied each night. The computation of these results is not yet completed, but there are indications of an anomaly near one of the stations. A full account of the work in this locality will be published in the near future.

Both areas surveyed in this test were of a hilly character, hitherto considered unsuitable for the employment of the Eötvös Balance, owing to the difficulty of calculating gravity effects of the topographical features. The terrain in each case was of a fairly uniform slope, extending well beyond the area surveyed, so that the effects due to this slope could be assumed to act along a certain direction, viz.: the line of greatest slope. The effects due to the suspected lodes, of which the general direction was indicated by geological data, were at right angles to the topographical effects, and the latter could therefore be ignored.

This test is considered to be of importance, not merely as it verifies the suitability of the balance for general field work, but also because it demonstrates the utility of such a survey in a region characteristic of the mineral areas throughout Great Britain. In such areas, flat ground, free from topographical disturbing effects, can scarcely ever be expected.

Calculation of Mathematical Tables. — *Report of Committee* (Professor J. W. NICHOLSON, *Chairman ;* Dr. J. R. AIREY, *Secretary* ; Dr. D. WRINCH-NICHOLSON, Mr. T. W. CHAUNDY, Professors L. N. G. FILON, E. W. HOBSON, Mr. G. KENNEDY, *and* Professors A. LODGE, A. E. H. LOVE, H. M. MACDONALD, G. N. WATSON, *and* A. G. WEBSTER).

As indicated in last year's Report, the following tables have been prepared for publication for the Toronto Meeting :—

(1) Tables of sin θ and cos θ to fifteen places of decimals for values of θ in radians from 10·0 to 20·0 by intervals of 0·1 and from 20·0 to 50·0 by intervals of 0·5 radian, supplementing tables of these functions published in earlier reports of the Committee, viz., sin θ and cos θ to eleven places of decimals for values of θ from 0·000 to 1·600 by intervals of 0·001, with a short subsidiary table for purposes of interpolation, and Dr. Doodson's table giving one hundred values of sin θ and cos θ to fifteen places, θ ranging from 0·1 to 10·0 radians (Report, 1916) ; also sin θ and cos θ calculated to twenty-four places but reduced to fifteen to be uniform with the previous table for $\theta=0$ to 100 radians (Report 1923).

(2) Tables of the Lommel-Weber functions $\Omega_0(x)$ and $\Omega_1(x)$ were calculated seven years ago with a view to their publication in the report of the Committee for 1917, but war conditions made this impossible. These functions are related to those of Struve which Professor Watson has recently given to seven places of decimals in the collection of mathematical tables in his 'Theory of Bessel functions.'

(3) Tables of the Bessel-Clifford* functions $C_0(x)$ and $C_1(x)$ which were computed from the relation $C_0(x)=J_0(2\sqrt{x})$ and $C_1(x)=-\dfrac{d.C_0(x)}{dx}$. These functions of zero and unit orders are of some interest, apart from their practical applications, and the construction of the tables did not present much difficulty. For functions of fractional order, however, the calculation from the well-known Bessel functions is troublesome and perhaps unnecessary.

For next year's Report, it is suggested that the Association might undertake the publication of tables of the Bessel functions $J_{\pm\frac{n+1}{2}}(x)$ to twelve places of decimals for $x=1$ to $x=20$: for positive orders, the calculations have been carried to the point where the first significant figure is in the thirteenth place, and for negative orders where the value of the function does not exceed unity : also tables of the Lommel-Weber functions, $\Omega_{\frac{1}{2}}(x)$ and $\Omega_{-\frac{1}{2}}(x)$ to six places for values of the argument x from 0·00 to 20·00 by intervals of 0·02, and similar tables of $J_{\frac{1}{2}}(x)$ and $J_{-\frac{1}{2}}(x)$. The computation of tables of the Confluent Hypergeometric function† $M(\alpha.\ \gamma.\ x)$, in particular for $\gamma=\frac{1}{2}$, is nearing completion. Tables of this kind have been found especially useful for the numerical solution of differential equations of the type

$$\frac{d^2y}{dx^2}+(px+q)\cdot\frac{dy}{dx}+(lx^2+mx+n)y=0$$

and other equations occurring in physical and engineering problems.

Sines and Cosines (θ in radians).

From the tables of sin θ and cos θ published in last year's Report and the known values of sin α and cos α, where $\alpha=0·1$ radian and 0·5 radian,

$$\begin{aligned}\sin 0·1&=+0·09983\ 34166\ 468281 :\\ \cos 0·1&=+0·99500\ 41652\ 780257 :\\ \sin 0·5&=+0·47942\ 55386\ 042030\\ \cos 0·5&=+0·87758\ 25618\ 903727,\end{aligned}$$

the following table was constructed for intermediate values of θ by the relations $\sin(\theta+\alpha)=\sin\theta\cos\alpha+\cos\theta\sin\alpha$, etc. For this purpose, the first hundred multiples

* Sir George Greenhill, *Phil. Mag.*, vol. 38, November 1919.
† *Phil. Mag.*, vol. 36, July 1918.

of sin α and cos α were tabulated to eighteen places to facilitate the calculation of the products sin θ . cos α, etc., and each sine or cosine obtained from the above formulae checked by previous results.

These tables have been employed in calculating various functions from their asymptotic series. The functions $J_{\frac{1}{2}}(x)=\sqrt{\frac{2}{\pi x}}\,.\sin x$ and $J_{-\frac{1}{2}}(x)=\sqrt{\frac{2}{\pi x}}\,.\cos x$ have been computed to sixteen places of decimals and functions of higher or lower order obtained from the recurrence relation

$$J_{\nu+1}(x)=\frac{2\nu}{x}\,.\,J_{\nu}(x)-J_{\nu-1}(x).$$

A considerable number of errors have been found in Lommel's tables of Bessel functions of half-odd integral order and in the tables of Fresnel's Integrals.

Sines and Cosines of Angles in Circular Measure.

θ	Sin θ	Cos θ
10·0	—0·54402 11108 89370	—0·83907 15290 76452
10·1	—0·62507 06488 92882	—0·78056 81801 69184
10·2	—0·69987 46875 93543	—0·71426 56520 27200
10·3	—0·76768 58097 63582	—0·64082 64175 94994
10·4	—0·82782 64690 85653	—0·56098 42574 27229
10·5	—0·87969 57599 71670	—0·47553 69279 95993
10·6	—0·92277 54216 12807	—0·38533 81907 71829
10·7	—0·95663 50162 70188	—0·29128 92817 21345
10·8	—0·98093 62300 66491	—0·19432 99064 55335
10·9	—0·99543 62533 06377	—0·09542 88510 00951
11·0	—0·99999 02065 50703	+0·00442 56979 88051
11·1	—0·99455 25882 03989	+0·10423 60268 65697
11·2	—0·97917 77291 51317	+0·20300 48638 18751
11·3	—0·95401 92499 02089	+0·29974 53432 77014
11·4	—0·91932 85256 64676	+0·39349 08663 47891
11·5	—0·87545 21746 88429	+0·48330 47587 53006
11·6	—0·82282 85949 68709	+0·56828 96297 67974
11·7	—0·76198 35839 19033	+0·64759 63386 53876
11·8	—0·69352 50847 77123	+0·72043 24789 90838
11·9	—0·61813 71122 37034	+0·78607 02961 41039
12·0	—0·53657 29180 00435	+0·84385 39587 32492
12·1	—0·44964 74645 34601	+0·89320 61115 09323
12·2	—0·35822 92822 36828	+0·93363 36440 74638
12·3	—0·26323 17913 65802	+0·96473 26178 86610
12·4	—0·16560 41754 48310	+0·98619 23022 78864
12·5	—0·06632 18973 51201	+0·99779 82791 78581
12·6	+0·03362 30472 21137	+0·99943 45855 01005
12·7	+0·13323 20414 19943	+0·99108 48718 14253
12·8	+0·23150 98251 01538	+0·97283 25656 97436
12·9	+0·32747 44391 37693	+0·94486 00381 59861
13·0	+0·42016 70368 26641	+0·90744 67814 50196
13·1	+0·50866 14643 72374	+0·86096 66164 62306
13·2	+0·59207 35147 07224	+0·80588 39576 40450
13·3	+0·66956 97621 96602	+0·74274 91727 03670
13·4	+0·74037 58899 52448	+0·67219 30835 53468
13·5	+0·80378 44265 51621	+0·59492 06633 09892
13·6	+0·85916 18148 56496	+0·51170 39924 53149
13·7	+0·90595 47423 08462	+0·42337 45444 50665
13·8	+0·94369 56694 44105	+0·33081 48779 49048
13·9	+0·97200 75013 94976	+0·23494 98185 39823
14·0	+0·99060 73556 94870	+0·13673 72182 07834
14·1	+0·99930 93887 47918	+0·03715 83847 90826

Sines and Cosines of Angles in Circular Measure—contd.

θ	Sin θ			Cos θ		
14·2	+0·99802	66527	16362	−0·06279	17229	24082
14·3	+0·98677	19642	74613	−0·16211	44364	99718
14·4	+0·96565	77765	49278	−0·25981	73562	13755
14·5	+0·93489	50555	24683	−0·35492	42667	88705
14·6	+0·89479	11721	40504	−0·44648	48914	12266
14·7	+0·84574	68311	42934	−0·53358	43865	89118
14·8	+0·78825	20673	75317	−0·61535	24829	54720
14·9	+0·72288	13495	11976	−0·69097	21807	19126
15·0	+0·65028	78401	57117	−0·75968	79128	58821
15·1	+0·57119	68696	59988	−0·82081	30944	92668
15·2	+0·48639	86888	53799	−0·87373	69830	11080
15·3	+0·39674	05731	30613	−0·91793	07804	14293
15·4	+0·30311	83567	45703	−0·95295	29168	87180
15·5	+0·20646	74819	37797	−0·97845	34628	18884
15·6	+0·10775	36522	99444	−0·99417	76251	83815
15·7	+0·00796	31837	85937	−0·99996	82933	49340
15·8	−0·09190	68502	27681	−0·99576	76088	73289
15·9	−0·19085	85813	74189	−0·98161	75436	06384
16·0	−0·28790	33166	65065	−0·95765	94803	23385
16·1	−0·38207	14171	84008	−0·92413	28000	73130
16·2	−0·47242	19863	98467	−0·88137	24903	62234
16·3	−0·55805	22712	86779	−0·82980	57980	70649
16·4	−0·63810	66823	47949	−0·76994	79605	42071
16·5	−0·71178	53423	69123	−0·70239	70575	02714
16·6	−0·77835	20785	34298	−0·62782	80352	46387
16·7	−0·83714	17780	19747	−0·54698	59627	94235
16·8	−0·88756	70335	81504	−0·46067	85874	11363
16·9	−0·92912	40127	34369	−0·36976	82638	63172
17·0	−0·96139	74918	79557	−0·27516	33380	51597
17·1	−0·98406	50050	81643	−0·17780	90711	23117
17·2	−0·99690	00660	41596	−0·07867	81947	31839
17·3	−0·99977	44310	73011	+0·02123	88081	73645
17·4	−0·99265	93804	70633	+0·12094	35999	28476
17·5	−0·97562	60054	68158	+0·21943	99632	11459
17·6	−0·94884	44979	18124	+0·31574	37549	19242
17·7	−0·91258	24497	91184	+0·40889	27393	98880
17·8	−0·86720	21794	85582	+0·49795	62027	88415
17·9	−0·81315	71116	61488	+0·58204	42524	02124
18·0	−0·75098	72467	71676	+0·66031	67082	44080
18·1	−0·68131	37655	55501	+0·73199	14978	08946
18·2	−0·60483	28224	06284	+0·79635	24702	91926
18·3	−0·52230	85896	26732	+0·85275	65521	30873
18·4	−0·43456	56220	71895	+0·90064	01723	84769
18·5	−0·34248	06184	69613	+0·93952	48937	48256
18·6	−0·24697	36617	36622	+0·96902	21929	39050
18·7	−0·14899	90258	14198	+0·98883	73426	94146
18·8	−0·04953	56408	78368	+0·99877	23565	87210
18·9	+0·05042	26878	06813	+0·99872	79672	43502
19·0	+0·14987	72096	62952	+0·98870	46181	86669
19·1	+0·24783	42079	82958	+0·96880	24594	07210
19·2	+0·34331	49288	19896	+0·93922	03466	96871
19·3	+0·43536	53603	72893	+0·90025	38547	47305
19·4	+0·52306	57651	57698	+0·85229	23238	65464
19·5	+0·60553	98697	19601	+0·79581	49698	13944
19·6	+0·68196	36200	68135	+0·73138	60956	45498
19·7	+0·75157	34153	52149	+0·65964	94533	73461
19·8	+0·81367	37375	07105	+0·58132	18118	14436
19·9	+0·86764	41006	41668	+0·49718	57948	71204
20·0	+0·91294	52507	27628	+0·40808	20618	13392
20·5	+0·99682	97942	78799	−0·07956	35672	78540

Sines and Cosines of Angles in Circular Measure—contd.

θ	Sin θ			Cos θ		
21·0	+0·83665	56385	36056	—0·54772	92602	24268
21·5	+0·47163	90030	94196	—0·88179	17275	41324
22·0	—0·00885	13092	90404	—0·99996	08263	94637
22·5	—0·48717	45124	60510	—0·87330	46400	93516
23·0	—0·84622	04041	75171	—0·53283	30203	33398
23·5	—0·99808	20279	79396	—0·06190	52939	94421
24·0	—0·90557	83620	06624	+0·42417	90073	36997
24·5	—0·59135	75298	65124	+0·80640	94939	12255
25·0	—0·13235	17500	97773	+0·99120	28118	63474
25·5	+0·35905	83540	22168	+0·93331	51120	63922
26·0	+0·76255	84504	79603	+0·64691	93223	28640
26·5	+0·97935	76431	03917	+0·20213	51203	87182
27·0	+0·95637	59284	04503	—0·29213	88087	33836
27·5	+0·69924	00316	55098	—0·71488	69687	79665
28·0	+0·27090	57883	07869	—0·96260	58663	13567
28·5	—0·22375	56401	86796	—0·97464	52757	20658
29·0	—0·66363	38842	12968	—0·74805	75296	89000
29·5	—0·94103	14083	42954	—0·33831	92109	71055
30·0	—0·98803	16240	92862	+0·15425	14498	87584
30·5	—0·79312	72394	57285	+0·60905	59761	06356
31·0	—0·40403	76453	23065	+0·91474	23578	04531
31·5	+0·08397	44556	91747	+0·99646	79075	57125
32·0	+0·55142	66812	41691	+0·83422	33605	06510
32·5	+0·88387	04235	45831	+0·46773	18402	47074
33·0	+0·99991	18601	07267	—0·01327	67472	23059
33·5	+0·87114	00001	69176	—0·49103	47239	30240
34·0	+0·52908	26861	20024	—0·84857	02747	84605
34·5	+0·05748	74781	04925	—0·99834	62274	48742
35·0	—0·42818	26694	96151	—0·90369	22050	91507
35·5	—0·80901	87662	11906	—0·58778	28135	60387
36·0	—0·99177	88534	43116	—0·12796	36896	27405
36·5	—0·93171	68878	54706	+0·36318	54084	16062
37·0	—0·64353	81333	56999	+0·76541	40519	45343
37·5	—0·19779	87996	36462	+0·98024	26408	10108
38·0	+0·29636	85787	09385	+0·95507	36440	47295
38·5	+0·71797	45927	71644	+0·69606	93098	63890
39·0	+0·96379	53862	84088	+0·26664	29323	59937
39·5	+0·97364	54556	94978	—0·22806	69344	83100
40·0	+0·74511	31604	79349	—0·66693	80616	52262
40·5	+0·33415	11768	48421	—0·94251	94910	50883
41·0	—0·15862	26688	04709	—0·98733	92775	23826
41·5	—0·61256	01529	75470	—0·79042	39741	97816
42·0	—0·91652	15479	15634	—0·39998	53149	88351
42·5	—0·99608	65031	19594	+0·08838	36993	05806
43·0	—0·83177	47426	28598	+0·55511	33015	20626
43·5	—0·46381	55159	83827	+0·88593	18072	69982
44·0	+0·01770	19251	05414	+0·99984	33086	47691
44·5	+0·49488	53175	52628	+0·86895	82973	13993
45·0	+0·85090	35245	34118	+0·52532	19888	17730
45·5	+0·99859	08724	11770	+0·05306	85362	14025
46·0	+0·90178	83476	48809	—0·43217	79448	84778
46·5	+0·58419	65844	13286	—0·81161	21923	43025
47·0	+0·12357	31227	45224	—0·99233	54691	50929
47·5	—0·36730	53491	34191	—0·93010	04142	01289
48·0	—0·76825	46613	23667	—0·64014	43394	69200
48·5	—0·98110	84386	03097	—0·19345	86046	20712
49·0	—0·95375	26527	59472	+0·30059	25437	43637
49·5	—0·69288	49542	33696	+0·72104	81538	68082
50·0	—0·26237	48537	03929	+0·96496	60284	92113

Lommel-Weber Functions of Zero and Unit Orders.

The function $\Omega_n(x)$ defined by the integral $\frac{1}{\pi}\int_0^\pi \sin(x\sin\theta - n\theta)\,d\theta$ is related to the function $J_n(x)$ and occurs in a number of problems in the diffraction of light ‡ and in the propagation of electro-magnetic waves from a thin anchor ring. Lord Rayleigh's $K(x) = \Omega_0(x)$, ‖ $K_1(x) = x\left(\Omega_1(x) + \frac{2}{\pi}\right)$, whilst Struve's function

$$H_0(x) = \Omega_0(x) \text{ and } H_1(x) = \Omega_1(x) + \frac{2}{\pi}.$$

The tables below were calculated from $x = 0{\cdot}1$ to $x = 6{\cdot}0$ by intervals of $0{\cdot}1$ from the ascending series

$$\Omega_0(x) = \frac{2}{\pi}\left(x - \frac{x^3}{3^2} + \frac{x^5}{3^2\cdot 5^2} - \frac{x^7}{3^2\cdot 5^2\cdot 7^2} + \ldots\right)$$

$$\Omega_1(x) = -\frac{2}{\pi}\left(1 - \frac{x^2}{3} + \frac{x^4}{3^2\cdot 5} - \frac{x^6}{3^2\cdot 5^2\cdot 7} + \ldots\right)$$

For values of x from 6·0 to 16·0, the asymptotic expansions were employed.

$$\Omega_0(x) = -\frac{2}{\pi}\left\{G_0(x) - B_0(x)\right\}$$

$$\text{where } B_0(x) = \frac{1}{x} - \frac{1}{x^3} + \frac{3^2}{x^5} - \frac{3^2\cdot 5^2}{x^7} + \ldots\ldots$$

$$\text{and } \Omega_1(x) = -\frac{2}{\pi}\left\{G_1(x) - B_1(x)\right\}$$

$$\text{where } B_1(x) = \frac{1}{x^2}\left(1 - \frac{3}{x^2} + \frac{3^2\cdot 5}{x^4} - \frac{3^2\cdot 5^2\cdot 7}{x^6} + \ldots\right)$$

and $G_0(x)$ and $G_1(x)$ are Neumann functions or Bessel functions of the second kind: tables of these functions have been computed for $x = 0{\cdot}00$ to $16{\cdot}00$ and are given in the Report for 1912.

If the calculation of $B_0(x)$ and $B_1(x)$ from their asymptotic series is carried no further than the least term, these functions can only be found to three places of decimals, when x is 6. By the employment of the 'converging factor' method, six place accuracy can be obtained even for this small value of the argument. The least term of the asymptotic series, multiplied by the corresponding converging factor, is equivalent to the divergent part of the series.

For $B_0(x)$, if $x = 2n + \alpha$ and $-1 < \alpha < 1$, the converging factor is

$$\frac{1}{2} - \frac{\alpha}{2x} + \frac{1}{4x^2}(1 + 2\alpha - \alpha^2) - \frac{1}{4x^3}(3 + 2\alpha - 3\alpha^2)$$
$$+ \frac{1}{8x^4}(19 - 2\alpha - 20\alpha^2 + 2\alpha^3 + \alpha^4) \ldots$$

and for $B_1(x)$, under the same conditions,

$$\frac{1}{2} + \frac{1}{2x}(1 - \alpha) - \frac{1}{4x^2}(3 - 4\alpha + \alpha^2) + \frac{1}{4x^3}(5 - 10\alpha + 3\alpha^2)$$
$$- \frac{1}{8x^4}(13 - 58\alpha + 24\alpha^2 + 2\alpha^3 - \alpha^4) \quad \ldots$$

‡ H. Struve, *Annalen der Physik und Chemie*, vol. 17, p. 1013.
H. F. Weber, *Vierteljahrsschrift der Naturf. Gesell. in Zürich*, vol. 24, p. 48.
‖ Lord Rayleigh, *Theory of Sound*, vol. 2, pp. 164-5.

Table of 'Converging Factors.'

x	For $B_0(x)$	For $B_1(x)$
6·0	0·504 :	0·567
1	0·497 :	0·560
2	0·490 :	0·552 :
3	0·483 :	0·545 :
4	0·477	0·539
5	0·470	0·532
6	0·463 :	0·525
7	0·456 :	0·518 :
8	0·450	0·512
9	0·443 :	0·505 :
7·0	0·437 :	0·499

Intermediate values of $\Omega_0(x)$ and $\Omega_1(x)$ by intervals of 0·02 were then found by interpolation from central differences. The tables are given as calculated some years ago and are in substantial agreement with the values of the H_0 and H_1 functions in Watson's 'Theory of Bessel Functions.' The colon : represents half a unit approximately in the last place of decimals.

Lommel-Weber Ω Functions of Zero and Unit Orders.

x	$\Omega_0(x)$	$\Omega_1(x)$	x	$\Omega_0(x)$	$\Omega_1(x)$
0·00	+0·000000	—0·636620	0·70	+0·421842 :	—0·535988
·02	+0·012732	—0·636535	·72	+0·432506	—0·530358
·04	+0·025460 :	—0·636280 :	·74	+0·443056	—0·524592
·06	+0·038182	—0·635856	·76	+0·453489	—0·518692
·08	+0·050893 :	—0·635262	·78	+0·463802 :	—0·512660
0·10	+0·063591 :	—0·634499	0·80	+0·473994 :	—0·506497 :
·12	+0·076272 :	—0·633567	·82	+0·484061 :	—0·500206 :
·14	+0·088933	—0·632466	·84	+0·494002	—0·493790
·16	+0·101570	—0·631196 :	·86	+0·503812 :	—0·487249
·18	+0·114179 :	—0·629759	·88	+0·513491	—0·480585 :
0·20	+0·126759	—0·628154	0·90	+0·523035	—0·473802 :
·22	+0·139304 :	—0·626382	·92	+0·532442	—0·466901
·24	+0·151813	—0·624443 :	·94	+0·541710 :	—0·459884 :
·26	+0·164281 :	—0·622339	·96	+0·550837	—0·452754
·28	+0·176705 :	—0·620069 :	·98	+0·559819 :	—0·445512 :
0·30	+0·189083	—0·617635 :	1·00	+0·568656 :	—0·438162 :
·32	+0·201410	—0·615038	·02	+0·577345 :	—0·430705 :
·34	+0·213683 :	—0·612277	·04	+0·585884	—0·423144 :
·36	+0·225900	—0·609354 :	·06	+0·594270 :	—0·415481 :
·38	+0·238056 :	—0·606271	·08	+0·602502 :	—0·407719
0·40	+0·250149 :	—0·603027	1·10	+0·610578 :	—0·399860
·42	+0·262176 :	—0·599624 :	·12	+0·618496 :	—0·391906 :
·44	+0·274133 :	—0·596064	·14	+0·626254 :	—0·383861
·46	+0·286018	—0·592346 :	·16	+0·633850 :	—0·375726
·48	+0·297826 :	—0·588473 :	·18	+0·641283	—0·367504
0·50	+0·309556	—0·584446	1·20	+0·648550	—0·359198
·52	+0·321203 :	—0·580265 :	·22	+0·655650	—0·350810
·54	+0·332765 :	—0·575933 :	·24	+0·662582	—0·342343 :
·56	+0·344239 :	—0·571450 :	·26	+0·669343 :	—0·333800 :
·58	+0·355622 :	—0·566819	·28	+0·675933 :	—0·325184
0·60	+0·366911 :	—0·562040	1·30	+0·682350 :	—0·316496 :
·62	+0·378103	—0·557115	·32	+0·688593	—0·307741
·64	+0·389195	—0·552046	·34	+0·694659 :	—0·298920
·66	+0·400184	—0·546834	·36	+0·700549	—0·290036
·68	+0·411067 :	—0·541480 :	·38	+0·706260 :	—0·281092 :

Lommel-Weber Ω Functions of Zero and Unit Orders—contd.

x	$\Omega_0(x)$	$\Omega_1(x)$	x	$\Omega_0(x)$	$\Omega_1(x)$
1·40	+0·711792 :	−0·272092	2·60	+0·705422 :	+0·263747 :
·42	+0·717144	−0·263037	·62	+0·700076	+0·270876
·44	+0·722313 :	−0·253930 :	·64	+0·694588	+0·277895
·46	+0·727301	−0·244775 :	·66	+0·688961	+0·284802 :
·48	+0·732104 :	−0·235574 :	·68	+0·683196 :	+0·291597
1·50	+0·736723 :	−0·226331 :	2·70	+0·677298	+0·298276
·52	+0·741157 :	−0·217048	·72	+0·671266 :	+0·304838
·54	+0·745405	−0·207727 :	·74	+0·665105	+0·311281
·56	+0·749466	−0·198372 :	·76	+0·658816	+0·317603 :
·58	+0·753340	−0·188986 :	·78	+0·652401 :	+0·323803 :
1·60	+0·757025 :	−0·179572 :	2·80	+0·645864 :	+0·329880
·62	+0·760522 :	−0·170133	·82	+0·639207 :	+0·335830 :
·64	+0·763830 :	−0·160670 :	·84	+0·632432 :	+0·341654
·66	+0·766949	−0·151189	·86	+0·625542	+0·347349
·68	+0·769878	−0·141691	·88	+0·618539	+0·352913 :
1·70	+0·772617	−0·132179	2·90	+0·611426 :	+0·358346 :
·72	+0·775165	−0·122656 :	·92	+0·604206	+0·363646 :
·74	+0·777523	−0·113126	·94	+0·596881 :	+0·368812
·76	+0·779690	−0·103591	·96	+0·589454 :	+0·373842
·78	+0·781666 :	−0·094053 :	·98	+0·581928 :	+0·378735
1·80	+0·783452 :	−0·084517 :	3·00	+0·574306	+0·383490
·82	+0·785047 :	−0·074985 :	·02	+0·566590	+0·388105 :
·84	+0·786451 :	−0·065460	·04	+0·558783	+0·392580 :
·86	+0·787665 :	−0·055945	·06	+0·550887 :	+0·396914
·88	+0·788689 :	−0·046442	·08	+0·542907 :	+0·401105 :
1·90	+0·789523 :	−0·036955 :	3·10	+0·534844 :	+0·405153
·92	+0·790168	−0·027487	·12	+0·526702	+0·409056 :
·94	+0·790623	−0·018039 :	·14	+0·518483	+0·412815
·96	+0·790890	−0·008617	·16	+0·510190 :	+0·416427
·98	+0·790968	+0·000778 :	·18	+0·501827	+0·419892 :
2·00	+0·790859	+0·010144	3·20	+0·493395 :	+0·423210 :
·02	+0·790562 :	+0·019476 :	·22	+0·484899 :	+0·426380 :
·04	+0·790080	+0·028773 :	·24	+0·476341 :	+0·429401 :
·06	+0·789412	+0·038032	·26	+0·467724 :	+0·432273
·08	+0·788559	+0·047249	·28	+0·459051 :	+0·434995
2·10	+0·787522	+0·056422	3·30	+0·450326	+0·437566 :
·12	+0·786302 :	+0·065548	·32	+0·441550	+0·439987 :
·14	+0·784900 :	+0·074625	·34	+0·432727 :	+0·442257 :
·16	+0·783318	+0·083649	·36	+0·423861	+0·444376
·18	+0·781555	+0·092618 :	·38	+0·414953 :	+0·446342 :
2·20	+0·779613 :	+0·101530	3·40	+0·406008	+0·448157 :
·22	+0·777494	+0·110381	·42	+0·397028	+0·449821
·24	+0·775198 :	+0·119169 :	·44	+0·388016	+0·451332
·26	+0·772728	+0·127892	·46	+0·378975 :	+0·452691
·28	+0·770083 :	+0·136546 :	·48	+0·369909 :	+0·453898
2·30	+0·767266 :	+0·145130	3·50	+0·360821	+0·454952 :
·32	+0·764278 :	+0·153640 :	·52	+0·351712 :	+0·455855 :
·34	+0·761121 :	+0·162075	·54	+0·342587 :	+0·456606 :
·36	+0·757796 :	+0·170431 :	·56	+0·333449	+0·457206
·38	+0·754305	+0·178707 :	·58	+0·324300 :	+0·457654 :
2·40	+0·750648 :	+0·186900	3·60	+0·315144	+0·457952
·42	+0·746829 :	+0·195007	·62	+0·305983 :	+0·458098 :
·44	+0·742849	+0·203026 :	·64	+0·296821	+0·458095
·46	+0·738709	+0·210955 :	·66	+0·287660 :	+0·457941 :
·48	+0·734411	+0·218792 :	·68	+0·278504 :	+0·457639
2·50	+0·729957 :	+0·226534 :	3·70	+0·269356	+0·457188
·52	+0·725350 :	+0·234179 :	·72	+0·260218	+0·456588 :
·54	+0·720591 :	+0·241725 :	·74	+0·251093 :	+0·455842
·56	+0·715682	+0·249170	·76	+0·241985	+0·454948 :
·58	+0·710625	+0·256511 :	·78	+0·232896 :	+0·453909

Lommel-Weber Ω Functions of Zero and Unit Orders—contd.

x	$\Omega_0(x)$	$\Omega_1(x)$	x	$\Omega_0(x)$	$\Omega_1(x)$
3·80	+0·223830	+0·452724 :	5·00	—0·185217	+0·171192
·82	+0·214788 :	+0·451396	·02	—0·188571	+0·164243
·84	+0·205775	+0·449923 :	·04	—0·191786 :	+0·157269
·86	+0·196792 :	+0·448309	·06	—0·194862	+0·150272
·88	+0·187843 :	+0·446553	·08	—0·197797	+0·143255
3·90	+0·178931	+0·444656 :	5·10	—0·200592	+0·136220
·92	+0·170058	+0·442620 :	·12	—0·203246	+0·129170 :
·94	+0·161227 :	+0·440446 :	·14	—0·205758 :	+0·122108 :
·96	+0·152441 :	+0·438135 :	·16	—0·208130	+0·115036 :
·98	+0·143703	+0·435688 :	·18	—0·210360	+0·107957
4·00	+0·135014 :	+0·433107	5·20	—0·212448 :	+0·100873
·02	+0·126379 :	+0·430392 :	·22	—0·214395	+0·093787
·04	+0·117799 :	+0·427546	·24	—0·216200	+0·086701 :
·06	+0·109278 :	+0·424568 :	·26	—0·217863	+0·079618 :
·08	+0·100818	+0·421462	·28	—0·219384 :	+0·072541
4·10	+0·092421	+0·418228	5·30	—0·220764 :	+0·065471 :
·12	+0·084089 :	+0·414868	·32	—0·222003 :	+0·058412 :
·14	+0·075827	+0·411383 :	·34	—0·223101	+0·051366 :
·16	+0·067635	+0·407776	·36	—0·224058	+0·044335 :
·18	+0·059516 :	+0·404047	·38	—0·224874 :	+0·037323
4·20	+0·051474	+0·400199	5·40	—0·225551 :	+0·030331
·22	+0·043509 :	+0·396232 :	·42	—0·226088 :	+0·023361 :
·24	+0·035625 :	+0·392149 :	·44	—0·226486	+0·016417 :
·26	+0·027824	+0·387952 :	·46	—0·226745	+0·009501
·28	+0·020108	+0·383643	·48	—0·226866 :	+0·002615
4·30	+0·012479 :	+0·379222 :	5·50	—0·226850	—0·004238 :
·32	+0·004940	+0·374693	·52	—0·226697	—0·011057 :
·34	—0·002507 :	+0·370057	·54	—0·226408	—0·017839
·36	—0·009861 :	+0·365315 :	·56	—0·225983 :	—0·024580 :
·38	—0·017119 :	+0·360471	·58	—0·225425	—0·031280 :
4·40	—0·024280	+0·355525 :	5·60	—0·224732 :	—0·037936 :
·42	—0·031340	+0·350481	·62	—0·223907 :	—0·044545 :
·44	—0·038298 :	+0·345339 :	·64	—0·222951	—0·051106
·46	—0·045153	+0·340103	·66	—0·221864	—0·057615 :
·48	—0·051902	+0·334774	·68	—0·220647	—0·064071 :
4·50	—0·058543 :	+0·329354 :	5·70	—0·219301 :	—0·070472 :
·52	—0·065075 :	+0·323846 :	·72	—0·217828 :	—0·076816
·54	—0·071496 :	+0·318252 :	·74	—0·216229	—0·083099 :
·56	—0·077805	+0·312574 :	·76	—0·214505	—0·089321 :
·58	—0·083999	+0·306815	·78	—0·212657	—0·095480
4·60	—0·090077	+0·300976	5·80	—0·210686	—0·101572
·62	—0·096037 :	+0·295059 :	·82	—0·208594	—0·107596 :
·64	—0·101879	+0·289068 :	·84	—0·206382 :	—0·113551
·66	—0·107600	+0·283005	·86	—0·204052 :	—0·119434
·68	—0·113198 :	+0·276871 :	·88	—0·201606	—0·125243
4·70	—0·118674	+0·270670 :	5·90	—0·199043 :	—0·130976 :
·72	—0·124025	+0·264403 :	·92	—0·196367 :	—0·136632
·74	—0·129250	+0·258074 :	·94	—0·193579	—0·142209
·76	—0·134347 :	+0·251684 :	·96	—0·190679 :	—0·147704
·78	—0·139317	+0·245236 :	·98	—0·187671	—0·153116 :
4·80	—0·144157	+0·238733	6·00	—0·184555 :	—0·158444 :
·82	—0·148866	+0·232176 :	·02	—0·181334	—0·163686
·84	—0·153443 :	+0·225569 :	·04	—0·178008 :	—0·168839 :
·86	—0·157888 :	+0·218914	·06	—0·174581	—0·173903 :
·88	—0·162199 :	+0·212213 :	·08	—0·171053	—0·178876 :
4·90	—0·166376 :	+0·205469 :	6·10	—0·167426 :	—0·183757
·92	—0·170418	+0·198685	·12	—0·163703	—0·188543
·94	—0·174324	+0·191862 :	·14	—0·159885 :	—0·193233
·96	—0·178092 :	+0·185004 :	·16	—0·155974 :	—0·197826
·98	—0·181724	+0·178113 :	·18	—0·151973	—0·202321

Lommel-Weber Ω Functions of Zero and Unit Orders—contd.

x	$\Omega_0(x)$	$\Omega_1(x)$	x	$\Omega_0(x)$	$\Omega_1(x)$
6·20	−0·147882 :	−0·206716	7·40	+0·175328 :	−0·262010
·22	−0·143705	−0·211009 :	·42	+0·180543 :	−0·259466
·24	−0·139442 :	−0·215200 :	·44	+0·185706 :	−0·256822
·26	−0·135097 :	−0·219288	·46	+0·190816	−0·254080
·28	−0·130672	−0·223271	·48	+0·195869	−0·251241
6·30	−0·126167 :	−0·227147 :	7·50	+0·200865	−0·248306 :
·32	−0·121586 :	−0·230917	·52	+0·205800 :	−0·245278
·34	−0·116931 :	−0·234578 :	·54	+0·210675	−0·242157
·36	−0·112204 :	−0·238130 :	·56	+0·215486 :	−0·238944
·38	−0·107407	−0·241572 :	·58	+0·220232 :	−0·235642
6·40	−0·102542	−0·244903	7·60	+0·224911 :	−0·232251 :
·42	−0·097612	−0·248122	·62	+0·229522	−0·228774
·44	−0·092618	−0·251228	·64	+0·234062	−0·225212
·46	−0·087563 :	−0·254220	·66	+0·238530	−0·221566 :
·48	−0·082450	−0·257098	·68	+0·242924	−0·217839
6·50	−0·077280 :	−0·259860 :	7·70	+0·247243	−0·214031
·52	−0·072056 :	−0·262507 :	·72	+0·251485	−0·210145
·54	−0·066781	−0·265038	·74	+0·255648	−0·206182
·56	−0·061455 :	−0·267451	·76	+0·259731 :	−0·202144
·58	−0·056083 :	−0·269747	·78	+0·263733 :	−0·198033
6·60	−0·050666 :	−0·271924 :	7·80	+0·267652 :	−0·193850
·62	−0·045207	−0·273984	·82	+0·271487	−0·189598
·64	−0·039708	−0·275924	·84	+0·275235 :	−0·185278
·66	−0·034171	−0·277745	·86	+0·278897 :	−0·180892
·68	−0·028599	−0·279446	·88	+0·282471	−0·176442
6·70	−0·022994	−0·281027 :	7·90	+0·285955	−0·171929 :
·72	−0·017358 :	−0·282489	·92	+0·289348	−0·167357
·74	−0·011695	−0·283830	·94	+0·292649	−0·162726 :
·76	−0·006006	−0·285050 :	·96	+0·295856 :	−0·158039 :
·78	−0·000294	−0·286150 :	·98	+0·298970	−0·153297 :
6·80	+0·005439	−0·287129 :	8·00	+0·301988	−0·148503 :
·82	+0·011190 :	−0·287988 :	·02	+0·304910	−0·143659 :
·84	+0·016957 :	−0·288727	·04	+0·307734	−0·138766 :
·86	+0·022738 :	−0·289345	·06	+0·310460	−0·133827 :
·88	+0·028530 :	−0·289842 :	·08	+0·313087	−0·128844
6·90	+0·034331 :	−0·290219 :	8·10	+0·315613 :	−0·123818 :
·92	+0·040138 :	−0·290477	·12	+0·318039 :	−0·118752 :
·94	+0·045950	−0·290615	·14	+0·320363 :	−0·113648 :
·96	+0·051762 :	−0·290633 :	·16	+0·322585	−0·108509
·98	+0·057574 :	−0·290533	·18	+0·324703 :	−0·103335
7·00	+0·063383	−0·290314	8·20	+0·326718 :	−0·098129
·02	+0·069186	−0·289977	·22	+0·328628 :	−0·092893 :
·04	+0·074981 :	−0·289522	·24	+0·330434	−0·087630 :
·06	+0·080766	−0·288950	·26	+0·332133 :	−0·082342
·08	+0·086538 :	−0·288261 :	·28	+0·333727 :	−0·077030
7·10	+0·092296	−0·287456 :	8·30	+0·335214 :	−0·071697
·12	+0·098036	−0·286537	·32	+0·336595	−0·066344 :
·14	+0·103756 :	−0·285502 :	·34	+0·337868 :	−0·060975 :
·16	+0·109455 :	−0·284354	·36	+0·339034	−0·055591 :
·18	+0·115130	−0·283092 :	·38	+0·340092	−0·050195
7·20	+0·120778 :	−0·281718 :	8·40	+0·341042	−0·044787 :
·22	+0·126398	−0·280233	·42	+0·341883 :	−0·039372
·24	+0·131987	−0·278637 :	·44	+0·342617	−0·033950 :
·26	+0·137543	−0·276932	·46	+0·343241 :	−0·028524 :
·28	+0·143063 :	−0·275117 :	·48	+0·343758	−0·023096 :
7·30	+0·148546 :	−0·273196	8·50	+0·344165 :	−0·017668 :
·32	+0·153990 :	−0·271167 :	·52	+0·344464 :	−0·012243
·34	+0·159392 :	−0·269033 :	·54	+0·344655	−0·006822
·36	+0·164751	−0·266795	·56	+0·344737 :	−0·001407 :
·38	+0·170064	−0·264453 :	·58	+0·344711 :	+0·003998 :

Lommel-Weber Ω Functions of Zero and Unit Orders—contd.

x	$\Omega_0(x)$	$\Omega_1(x)$	x	$\Omega_0(x)$	$\Omega_1(x)$
8·60	+0·344577 :	+0·009393 :	9·80	+0·168863 :	+0·244339 :
·62	+0·344335 :	+0·014776	·82	+0·163961 :	+0·245870
·64	+0·343986 :	+0·020143 :	·84	+0·159029 :	+0·247303
·66	+0·343530	+0·025494	·86	+0·154070	+0·248638
·68	+0·342966 :	+0·030825 :	·88	+0·149084 :	+0·249874 :
8·70	+0·342297	+0·036136 :	9·90	+0·144075 :	+0·251012 :
·72	+0·341521 :	+0·041424	·92	+0·139045	+0·252051
·74	+0·340640 :	+0·046686	·94	+0·133994	+0·252990 :
·76	+0·339654 :	+0·051921 :	·96	+0·128926	+0·253831
·78	+0·338564	+0·057127 :	·98	+0·123841 :	+0·254571 :
8·80	+0·337369 :	+0·062303	10·00	+0·118743 :	+0·255213
·82	+0·336072	+0·067445	·02	+0·113634	+0·255754
·84	+0·334672	+0·072552	·04	+0·108514	+0·256196
·86	+0·333170	+0·077622	·06	+0·103386 :	+0·256537 :
·88	+0·331567	+0·082653 :	·08	+0·098253 :	+0·256780
8·90	+0·329864	+0·087644 :	10·10	+0·093116	+0·256922 :
·92	+0·328062	+0·092592 :	·12	+0·087977	+0·256966
·94	+0·326161	+0·097496	·14	+0·082838	+0·256910
·96	+0·324162	+0·102353 :	·16	+0·077701 :	+0·256754 :
·98	+0·322067	+0·107163	·18	+0·072568 :	+0·256500 :
9·00	+0·319876	+0·111923	10·20	+0·067442	+0·256148
·02	+0·317590 :	+0·116631	·22	+0·062323 :	+0·255697
·04	+0·315211	+0·121285 :	·24	+0·057214 :	+0·255148 :
·06	+0·312739 :	+0·125885	·26	+0·052118	+0·254502 :
·08	+0·310176	+0·130428	·28	+0·047035	+0·253759 :
9·10	+0·307522 :	+0·134912 :	10·30	+0·041968 :	+0·252919 :
·12	+0·304780	+0·139337	·32	+0·036919	+0·251984
·14	+0·301949 :	+0·143699 :	·34	+0·031889 :	+0·250952 :
·16	+0·299032 :	+0·147999 :	·36	+0·026881 :	+0·249826
·18	+0·296030	+0·152234	·38	+0·021897	+0·248605 :
9·20	+0·292943 :	+0·156403	10·40	+0·016938	+0·247291
·22	+0·289774 :	+0·160503 :	·42	+0·012006 :	+0·245883 :
·24	+0·286524	+0·164535	·44	+0·007103 :	+0·244384
·26	+0·283193 :	+0·168496	·46	+0·002231 :	+0·242792 :
·28	+0·279784 :	+0·172384 :	·48	−0·002607 :	+0·241110 :
9·30	+0·276298 :	+0·176199 :	10·50	−0·007412 :	+0·239338 :
·32	+0·272737	+0·179940	·52	−0·012180 :	+0·237477
·34	+0·269101 :	+0·183604	·54	−0·016911	+0·235528
·36	+0·265393	+0·187191	·56	−0·021601 :	+0·233491
·38	+0·261614	+0·190699	·58	−0·026250	+0·231368
9·40	+0·257766	+0·194127	10·60	−0·030855 :	+0·229160
·42	+0·253849 :	+0·197474	·62	−0·035416	+0·226867 :
·44	+0·249867 :	+0·200739	·64	−0·039929 :	+0·224491 :
·46	+0·245820 :	+0·203920	·66	−0·044395	+0·222033
·48	+0·241711	+0·207017	·68	−0·048810 :	+0·219494
9·50	+0·237540 :	+0·210029	10·70	−0·053174	+0·216875
·52	+0·233310 :	+0·212954	·72	−0·057484 :	+0·214177
·54	+0·229023	+0·215791 :	·74	−0·061740 :	+0·211401
·56	+0·224679 :	+0·218540 :	·76	−0·065940	+0·208549
·58	+0·220282	+0·221200	·78	−0·070082	+0·205622
9·60	+0·215832	+0·223769 :	10·80	−0·074164 :	+0·202621
·62	+0·211332	+0·226248	·82	−0·078186 :	+0·199547 :
·64	+0·206783	+0·228635	·84	−0·082146	+0·196402 :
·66	+0·202187	+0·230929	·86	−0·086042	+0·193188
·68	+0·197546 :	+0·233129 :	·88	−0·089873	+0·189905
9·70	+0·192862 :	+0·235236 :	10·90	−0·093638	+0·186555
·72	+0·188137 :	+0·237248 :	·92	−0·097335	+0·183139 :
·74	+0·183373 :	+0·239165 :	·94	−0·100963	+0·179659 :
·76	+0·178571 :	+0·240986 :	·96	−0·104521	+0·176116 :
·78	+0·173734 :	+0·242711 :	·98	−0·108007	+0·172513

Lommel-Weber Ω Functions of Zero and Unit Orders—contd.

x	$\Omega_0(x)$	$\Omega_1(x)$	x	$\Omega_0(x)$	$\Omega_1(x)$
11·00	−0·111421	+0·168849 :	12·20	−0·157672	−0·095220
·02	−0·114761	+0·165127 :	·22	−0·155727 :	−0·099238
·04	−0·118025 :	+0·161349 :	·24	−0·153703	−0·103208
·06	−0·121214 :	+0·157516	·26	−0·151599 :	−0·107128 :
·08	−0·124326	+0·153629	·28	−0·149418	−0·110999
11·10	−0·127359 :	+0·149690 :	12·30	−0·147159 :	−0·114817
·12	−0·130313 :	+0·145701 :	·32	−0·144825 :	−0·118581 :
·14	−0·133187	+0·141664 :	·34	−0·142417	−0·122291 :
·16	−0·135979 :	+0·137580 :	·36	−0·139934	−0·125945
·18	−0·138690	+0·133451	·38	−0·137379	−0·129541
11·20	−0·141317	+0·129278	12·40	−0·134753	−0·133078
·22	−0·143860 :	+0·125063 :	·42	−0·132056 :	−0·136555
·24	−0·146319 :	+0·120809	·44	−0·129291 :	−0·139970 :
·26	−0·148693	+0·116516	·46	−0·126458	−0·143323 :
·28	−0·150980	+0·112186 :	·48	−0·123559	−0·146612
11·30	−0·153180	+0·107822	12·50	−0·120594 :	−0·149836
·32	−0·155292 :	+0·103424 :	·52	−0·117566	−0·152993 :
·34	−0·157317	+0·098995 :	·54	−0·114475	−0·156083
·36	−0·159252	+0·094537 :	·56	−0·111323	−0·159104 :
·38	−0·161098	+0·090052	·58	−0·108111 :	−0·162056 :
11·40	−0·162854	+0·085540	12·60	−0·104841	−0·164938
·42	−0·164519 :	+0·081004 :	·62	−0·101514	−0·167747 :
·44	−0·166094 :	+0·076446 :	·64	−0·098132	−0·170484
·46	−0·167577 :	+0·071868	·66	−0·094695 :	−0·173147 :
·48	−0·168969	+0·067271	·68	−0·091206 :	−0·175736
11·50	−0·170268	+0·062657	12·70	−0·087666 :	−0·178249
·52	−0·171475	+0·058028 :	·72	−0·084077	−0·180686
·54	−0·172589	+0·053386 :	·74	−0·080439 :	−0·183046
·56	−0·173610	+0·048734	·76	−0·076755 :	−0·185327 :
·58	−0·174538 :	+0·044071 :	·78	−0·073027	−0·187530 :
11·60	−0·175373	+0·039401 :	12·80	−0·069255	−0·189654
·62	−0·176114 :	+0·034726	·82	−0·065441 :	−0·191697
·64	−0·176762	+0·030047	·84	−0·061587 :	−0·193659 :
·66	−0·177316	+0·025365 :	·86	−0·057695 :	−0·195540 :
·68	−0·177776 :	+0·020683 :	·88	−0·053766 :	−0·197339
11·70	−0·178143 :	+0·016004	12·90	−0·049802 :	−0·199055
·72	−0·178417	+0·011327 :	·92	−0·045805	−0·200687 :
·74	−0·178597	+0·006656	·94	−0·041775 :	−0·202236 :
·76	−0·178683 :	+0·001992 :	·96	−0·037716	−0·203701 :
·78	−0·178676 :	−0·002662 :	·98	−0·033628	−0·205081 :
11·80	−0·178577	−0·007306 :	13·00	−0·029513	−0·206376
·82	−0·178384 :	−0·011938	·02	−0·025373 :	−0·207585 :
·84	−0·178099 :	−0·016555 :	·04	−0·021210 :	−0·208709
·86	−0·177722	−0·021156 :	·06	−0·017025 :	−0·209746 :
·88	−0·177253	−0·025739 :	·08	−0·012821	−0·210697 :
11·90	−0·176693	−0·030303	13·10	−0·008598 :	−0·211562
·92	−0·176041	−0·034844 :	·12	−0·004359 :	−0·212339 :
·94	−0·175299	−0·039363	·14	−0·000105 :	−0·213029 :
·96	−0·174467	−0·043857	·16	+0·004161 :	−0·213633
·98	−0·173545	−0·048324	·18	+0·008439	−0·214149
12·00	−0·172534	−0·052762 :	13·20	+0·012726 :	−0·214577 :
·02	−0·171434 :	−0·057171	·22	+0·017022	−0·214918 :
·04	−0·170247 :	−0·061547 :	·24	+0·021323	−0·215172 :
·06	−0·168973	−0·065891	·26	+0·025628	−0·215339
·08	−0·167612	−0·070199	·28	+0·029936	−0·215418 :
12·10	−0·166165 :	−0·074470 :	13·30	+0·034244 :	−0·215410 :
·12	−0·164633 :	−0·078703 :	·32	+0·038552	−0·215315 :
·14	−0·163017 :	−0·082896	·34	+0·042856 :	−0·215133 :
·16	−0·161318	−0·087048	·36	+0·047156 :	−0·214865
·18	−0·159536	−0·091156	·38	+0·051450 :	−0·214510

Lommel-Weber Ω Functions of Zero and Unit Orders—contd.

x	$\Omega_0(x)$	$\Omega_1(x)$	x	$\Omega_0(x)$	$\Omega_1(x)$
13·40	+0·055736 :	−0·214069	14·60	+0·240823 :	−0·058203 :
·42	+0·060012 :	−0·213542	·62	+0·241947 :	−0·054170
·44	+0·064277 :	−0·212930	·64	+0·242990 :	−0·050119 :
·46	+0·068529 :	−0·212232	·66	+0·243952	−0·046053 :
·48	+0·072766 :	−0·211450	·68	+0·244832 :	−0·041973 :
13·50	+0·076986 :	−0·210583	14·70	+0·245631	−0·037881
·52	+0·081189	−0·209632 :	·72	+0·246347 :	−0·033778
·54	+0·085371 :	−0·208599	·74	+0·246982	−0·029666
·56	+0·089532 :	−0·207482 :	·76	+0·247534	−0·025546 :
·58	+0·093670	−0·206284	·78	+0·248004	−0·021421
13·60	+0·097783	−0·205003 :	14·80	+0·248391	−0·017291 :
·62	+0·101869 :	−0·203642 :	·82	+0·248695 :	−0·013160
·64	+0·105928	−0·202200 :	·84	+0·248917 :	−0·009027
·66	+0·109957	−0·200679 :	·86	+0·249056 :	−0·004895 :
·68	+0·113955	−0·199079	·88	+0·249113	−0·000766
13·70	+0·117920	−0·197400 :	14·90	+0·249087	+0·003359 :
·72	+0·121850 :	−0·195645	·92	+0·248978 :	+0·007479
·74	+0·125745	−0·193812 :	·94	+0·248788	+0·011591
·76	+0·129602 :	−0·191904 :	·96	+0·248515	+0·015694 :
·78	+0·133421	−0·189921 :	·98	+0·248160	+0·019787
13·80	+0·137199	−0·187864 :	15·00	+0·247723 :	+0·023867 :
·82	+0·140935	−0·185734 :	·02	+0·247205 :	+0·027934
·84	+0·144628	−0·183532 :	·04	+0·246606 :	+0·031985 :
·86	+0·148276	−0·181259 :	·06	+0·245926 :	+0·036019 :
·88	+0·151877 :	−0·178916	·08	+0·245166	+0·040035 :
13·90	+0·155432	−0·176503 :	15·10	+0·244325	+0·044031
·92	+0·158937 :	−0·174023 :	·12	+0·243405	+0·048005
·94	+0·162392 :	−0·171476	·14	+0·242405	+0·051955 :
·96	+0·165796	−0·168862 :	·16	+0·241327	+0·055881 :
·98	+0·169146 :	−0·166185	·18	+0·240170	+0·059781
14·00	+0·172443	−0·163443	15·20	+0·238935 :	+0·063652 :
·02	+0·175684	−0·160639 :	·22	+0·237624	+0·067495
·04	+0·178868	−0·157774 :	·24	+0·236236	+0·071306 :
·06	+0·181994 :	−0·154849 :	·26	+0·234772	+0·075086
·08	+0·185061 :	−0·151865 :	·28	+0·233233	+0·078831 :
14·10	+0·188068 :	−0·148824 :	15·30	+0·231619	+0·082541 :
·12	+0·191014 :	−0·145727	·32	+0·229931 :	+0·086215 :
·14	+0·193897 :	−0·142575	·34	+0·228170 :	+0·089851
·16	+0·196717	−0·139369	·36	+0·226337 :	+0·093447 :
·18	+0·199471 :	−0·136111	·38	+0·224433	+0·097003
14·20	+0·202161	−0·132802 :	15·40	+0·222458	+0·100516 :
·22	+0·204783 :	−0·129444 :	·42	+0·220412 :	+0·103986 :
·24	+0·207338 :	−0·126038 :	·44	+0·218298 :	+0·107411 :
·26	+0·209825	−0·122585 :	·46	+0·216116 :	+0·110790 :
·28	+0·212241 :	−0·119087 :	·48	+0·213867 :	+0·114122
14·30	+0·214588	−0·115546	15·50	+0·211552	+0·117404 :
·32	+0·216863	−0·111962 :	·52	+0·209171 :	+0·120637 :
·34	+0·219066 :	−0·108337 :	·54	+0·206727	+0·123819 :
·36	+0·221196 :	−0·104673 :	·56	+0·204219	+0·126949
·38	+0·223253	−0·100972	·58	+0·201649 :	+0·130025
14·40	+0·225235	−0·097234	15·60	+0·199018 :	+0·133046
·42	+0·227142	−0·093461 :	·62	+0·196328	+0·136011 :
·44	+0·228973	−0·089655 :	·64	+0·193578 :	+0·138920 :
·46	+0·230728	−0·085818	·66	+0·190771 :	+0·141771
·48	+0·232405 :	−0·081950 :	·68	+0·187908	+0·144562 :
14·50	+0·234006	−0·078054 :	15·70	+0·184989	+0·147294
·52	+0·235527 :	−0·074132	·72	+0·182016 :	+0·149964 :
·54	+0·236971	−0·070183 :	·74	+0·178991	+0·152573
·56	+0·238335	−0·066211 :	·76	+0·175914	+0·155118 :
·58	+0·239619 :	−0·062218	·78	+0·172786 :	+0·157600

Lommel-Weber Ω Functions of Zero and Unit Orders—contd.

x	$\Omega_0(x)$	$\Omega_1(x)$	x	$\Omega_0(x)$	$\Omega_1(x)$
15·80	+0·169610 :	+0·160016 :	15·90	+0·153040 :	+0·171096 :
·82	+0·166386 :	+0·162367	·92	+0·149598 :	+0·173106 :
·84	+0·163116	+0·164651 :	·94	+0·146117	+0·175045 :
·86	+0·159801	+0·166868	·96	+0·142597	+0·176914
·88	+0·156442	+0·169017	·98	+0·139041	+0·178710 :
			16·00	+0·135449 :	+0·180434 :

Bessel-Clifford Functions of Zero and Unit Orders.

The function $C_0(x)$ is defined by the series

$$\sum_{k=0}^{\infty}(-x)^k/(\Pi k)^2 = J_0(2\sqrt{x}) = 1 - x + \frac{x^2}{2\,!^2} - \frac{x^3}{3\,!^2} + \frac{x^4}{4\,!^2} - \frac{x^5}{5\,!^2} + \ldots .$$

The successive derivatives of $C_0(x)$ give the series which represent the functions of higher integral order in accordance with the definition

$$C_n(x) = (-)^n \cdot \frac{d^n \cdot C_0(x)}{dx^n} = \sum_{k=0}^{\infty} (-x)^k/\Pi(n+k)\Pi(k),$$

$$\text{and } C_1(x) = -\frac{d \cdot C_0(x)}{dx} = 1 - \frac{x}{2\,!} + \frac{x^2}{2\,!\,3\,!} - \frac{x^3}{3\,!\,4\,!} + \ldots$$

Commencing with the two hundred values of x from 0·1 to 20·0, $z=2\sqrt{x}$ was obtained in each case to nine significant figures, from tables of square roots and the corresponding values of $J_0(z)$ calculated from Meissel's well-known table: $C_1(x)$, the first derivative of $C_0(x)$, was found from central differences by the relation

$$\frac{d \cdot f(a)}{da} = \frac{1}{\omega}\left[f'(a) - \frac{1}{6}f'''(a) + \frac{1}{30}f^v(a) \ldots\right]$$

The more important properties and the applications of the Bessel-Clifford functions are set out in detail by Sir George Greenhill in the *Phil. Mag.*, Nov. 1919.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
0·00	+1·000000	+1·000000	0·50	+0·559134	+0·769986 :
·02	+0·980100	+0·990033 :	·52	+0·543818 :	+0·761582
·04	+0·960398	+0·980133	·54	+0·528670 :	+0·753235 :
·06	+0·940894	+0·970298 :	·56	+0·513689	+0·744947 :
·08	+0·921586	+0·960530	·58	+0·498872	+0·736717
0·10	+0·902472 :	+0·950826 :	0·60	+0·484219 :	+0·728544
·12	+0·883552 :	+0·941188	·62	+0·469730	+0·720428 :
·14	+0·864824 :	+0·931614 :	·64	+0·455402	+0·712370
·16	+0·846287 :	+0·922105	·66	+0·441235	+0·704368
·18	+0·827940	+0·912660	·68	+0·427227	+0·696422 :
0·20	+0·809780 :	+0·903278 :	0·70	+0·413377 :	+0·688533
·22	+0·791808	+0·893960	·72	+0·399685 :	+0·680699
·24	+0·774021 :	+0·884705	·74	+0·386149 :	+0·672921
·26	+0·756419 :	+0·875513	·76	+0·372768	+0·665198
·28	+0·739001	+0·866383	·78	+0·359541	+0·657529 :
0·30	+0·721764	+0·857315 :	0·80	+0·346466 :	+0·649916
·32	+0·704708	+0·848309 :	·82	+0·333544	+0·642357
·34	+0·687831	+0·839365	·84	+0·320772	+0·634852
·36	+0·671132 :	+0·830482	·86	+0·308149 :	+0·627401
·38	+0·654611 :	+0·821659 :	·88	+0·295675 :	+0·620003
0·40	+0·638266	+0·812897 :	0·90	+0·283349	+0·612658 :
·42	+0·622095	+0·804196	·92	+0·271169	+0·605367
·44	+0·606098	+0·795554 :	·94	+0·259134	+0·598128
·46	+0·590272 :	+0·786972 :	·96	+0·247243 :	+0·590941 :
·48	+0·574618 :	+0·778450	·98	+0·235496	+0·583807 :

Bessel-Clifford Functions of Zero and Unit Orders—contd.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
1·00	+0·223891	+0·576725	2·20	—0·248478	+0·236956 :
·02	+0·212426 :	+0·569694	·22	—0·253173	+0·232562
·04	+0·201102 :	+0·562714 :	·24	—0·257780 :	+0·228204 :
·06	+0·189918	+0·555785 :	·26	—0·262301 :	+0·223883 :
·08	+0·178871	+0·548908	·28	—0·266736 :	+0·219599
1·10	+0·167961	+0·542080 :	2·30	—0·271086	+0·215351
·12	+0·157187 :	+0·535303 :	·32	—0·275350 :	+0·211139 :
·14	+0·146548 :	+0·528576 :	·34	—0·279531 :	+0·206963 :
·16	+0·136044	+0·521899	·36	—0·283629 :	+0·202823
·18	+0·125672 :	+0·515271	·38	—0·287644 :	+0·198718 :
1·20	+0·115433	+0·508692	2·40	—0·291578 :	+0·194649
·22	+0·105324 :	+0·502162	·42	—0·295431	+0·190614 :
·24	+0·095346	+0·495681	·44	—0·299203	+0·186615
·26	+0·085497	+0·489248	·46	—0·302896	+0·182650
·28	+0·075776	+0·482863	·48	—0·306509 :	+0·178720
1·30	+0·066182	+0·476526 :	2·50	—0·310045	+0·174824
·32	+0·056714 :	+0·470237	·52	—0·313502 :	+0·170962
·34	+0·047372	+0·463995 :	·54	—0·316883 :	+0·167134
·36	+0·038154 :	+0·457800 :	·56	—0·320188	+0·163339 :
·38	+0·029060	+0·451652 :	·58	—0·323417 :	+0·159578 :
1·40	+0·020088	+0·445551 :	2·60	—0·326571 :	+0·155851
·42	+0·011237 :	+0·439496 :	·62	—0·329651 :	+0·152156 :
·44	+0·002507 :	+0·433487 :	·64	—0·332658	+0·148495
·46	—0·006102 :	+0·427525	·66	—0·335591 :	+0·144866 :
·48	—0·014593 :	+0·421607 :	·68	—0·338453	+0·141270
1·50	—0·022967	+0·415735 :	2·70	—0·341242 :	+0·137706 :
·52	—0·031223 :	+0·409908 :	·72	—0·343961 :	+0·134174 :
·54	—0·039363 :	+0·404126 :	·74	—0·346610	+0·130675
·56	—0·047388 :	+0·398389 :	·76	—0·349188 :	+0·127207
·58	—0·055299 :	+0·392696 :	·78	—0·351698 :	+0·123770 :
1·60	—0·063097	+0·387047 :	2·80	—0·354139 :	+0·120365 :
·62	—0·070781 :	+0·381442 :	·82	—0·356513	+0·116992
·64	—0·078355	+0·375881 :	·84	—0·358819 :	+0·113649
·66	—0·085817	+0·370364	·86	—0·361059 :	+0·110337 :
·68	—0·093169 :	+0·364889	·88	—0·363233	+0·107056
1·70	—0·100413	+0·359457 :	2·90	—0·365342	+0·103805 :
·72	—0·107548 :	+0·354068 :	·92	—0·367385 :	+0·100585
·74	—0·114576	+0·348722	·94	—0·369365 :	+0·097395
·76	—0·121497 :	+0·343418	·96	—0·371281 :	+0·094234 :
·78	—0·128313	+0·338155 :	·98	—0·373135	+0·091104
1·80	—0·135024	+0·332935 :	3·00	—0·374926	+0·088003
·82	—0·141631	+0·327756 :	·02	—0·376655 :	+0·084931 :
·84	—0·148134 :	+0·322619	·04	—0·378323 :	+0·081889
·86	—0·154536	+0·317522 :	·06	—0·379931	+0·078876
·88	—0·160835 :	+0·312467	·08	—0·381478 :	+0·075891 :
1·90	—0·167035	+0·307452 :	3·10	—0·382967	+0·072936
·92	—0·173134	+0·302478	·12	—0·384396 :	+0·070009
·94	—0·179134	+0·297543 :	·14	—0·385767 :	+0·067110 :
·96	—0·185036	+0·292649 :	·16	—0·387081	+0·064240
·98	—0·190840 :	+0·287795	·18	—0·388337	+0·061397 :
2·00	—0·196548	+0·282980	3·20	—0·389537	+0·058582 :
·02	—0·202160	+0·278204 :	·22	—0·390680 :	+0·055796
·04	—0·207676 :	+0·273467 :	·24	—0·391769	+0·053036 :
·06	—0·213099	+0·268770	·26	—0·392802 :	+0·050304 :
·08	—0·218427 :	+0·264111	·28	—0·393781 :	+0·047599 :
2·10	—0·223663 :	+0·259490 :	3·30	—0·394706 :	+0·044921 :
·12	—0·228807 :	+0·254908	·32	—0·395578 :	+0·042270 :
·14	—0·233860	+0·250363 :	·34	—0·396397 :	+0·039646
·16	—0·238822 :	+0·245857	·36	—0·397164 :	+0·037048 :
·18	—0·243694 :	+0·241388	·38	—0·397879 :	+0·034477

Bessel-Clifford Functions of Zero and Unit Orders—contd.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
3·40	—0·398543 :	+0·031931 :	4·60	—0·362794 :	—0·078573
·42	—0·399157	+0·029412 :	·62	—0·361211	—0·079799 :
·44	—0·399720 :	+0·026919	·64	—0·359602 :	—0·081009
·46	—0·400234	+0·024451 :	·66	—0·357970 :	—0·082201 :
·48	—0·400698 :	+0·022009 :	·68	—0·356314 :	—0·083376 :
3·50	—0·401114 :	+0·019593	4·70	—0·354635 :	—0·084534
·52	—0·401482 :	+0·017201 :	·72	—0·352933 :	—0·085675
·54	—0·401803	+0·014835	·74	—0·351208 :	—0·086799
·56	—0·402076	+0·012493 :	·76	—0·349461 :	—0·087906 :
·58	—0·402302 :	+0·010177	·78	—0·347692 :	—0·088997
3·60	—0·402483 :	+0·007885	4·80	—0·345902	—0·090071 :
·62	—0·402618	+0·005617	·82	—0·344090	—0·091129
·64	—0·402708	+0·003374	·84	—0·342257	—0·092170 :
·66	—0·402753 :	+0·001154 :	·86	—0·340403	—0·093196
·68	—0·402754 :	—0·001040 :	·88	—0·338529	—0·094205 :
3·70	—0·402712	—0·003212	4·90	—0·336635	—0·095199
·72	—0·402626	—0·005359 :	·92	—0·334721	—0·096176 :
·74	—0·402497 :	—0·007483 :	·94	—0·332788	—0·097138
·76	—0·402327	—0·009584 :	·96	—0·330836	—0·098084 :
·78	—0·402114 :	—0·011662	·98	—0·328865	—0·099015 :
3·80	—0·401860 :	—0·013716	5·00	—0·326875 :	—0·099930 :
·82	—0·401566	—0·015747 :	·02	—0·324867 :	—0·100831
·84	—0·401231	—0·017756	·04	—0·322842	—0·101716
·86	—0·400856	—0·019742	·06	—0·320799	—0·102586
·88	—0·400441 :	—0·021705 :	·08	—0·318739	—0·103441
3·90	—0·399988	—0·023646 :	5·10	—0·316661 :	—0·104281
·92	—0·399495 :	—0·025565 :	·12	—0·314567 :	—0·105106 :
·94	—0·398965 :	—0·027462 :	·14	—0·312457 :	—0·105917 :
·96	—0·398397 :	—0·029337	·16	—0·310331	—0·106714
·98	—0·397792	—0·031190	·18	—0·308189	—0·107496
4·00	—0·397150	—0·033021 :	5·20	—0·306031 :	—0·108264
·02	—0·396471	—0·034831 :	·22	—0·303858 :	—0·109017 :
·04	—0·395756 :	—0·036620	·24	—0·301670 :	—0·109757
·06	—0·395006 :	—0·038387 :	·26	—0·299468 :	—0·110482 :
·08	—0·394221 :	—0·040133 :	·28	—0·297251 :	—0·111194
4·10	—0·393401 :	—0·041859	5·30	—0·295020 :	—0·111892
·12	—0·392547	—0·043563 :	·32	—0·292776	—0·112576
·14	—0·391659	—0·045247	·34	—0·290517 :	—0·113247
·16	—0·390737 :	—0·046910 :	·36	—0·288246	—0·113904
·18	—0·389782 :	—0·048553	·38	—0·285961 :	—0·114548
4·20	—0·388795 :	—0·050176	5·40	—0·283664 :	—0·115178 :
·22	—0·387776	—0·051778	·42	—0·281354 :	—0·115796
·24	—0·386724 :	—0·053360 :	·44	—0·279032 :	—0·116400 :
·26	—0·385641 :	—0·054923	·46	—0·276698 :	—0·116992
·28	—0·384527 :	—0·056466	·48	—0·274353	—0·117570 :
4·30	—0·383383	—0·057989	5·50	—0·271996	—0·118136 :
·32	—0·382208	—0·059493	·52	—0·269627 :	—0·118689 :
·34	—0·381003 :	—0·060977 :	·54	—0·267248 :	—0·119230
·36	—0·379769	—0·062442 :	·56	—0·264858 :	—0·119758
·38	—0·378506	—0·063888 :	·58	—0·262458	—0·120274
4·40	—0·377214	—0·065316	5·60	—0·260047 :	—0·120777 :
·42	—0·375893 :	—0·066724	·62	—0·257627	—0·121269
·44	—0·374545	—0·068114	·64	—0·255197	—0·121748
·46	—0·373169	—0·069485	·66	—0·252757 :	—0·122215 :
·48	—0·371765 :	—0·070837 :	·68	—0·250308 :	—0·122670 :
4·50	—0·370335 :	—0·072172	5·70	—0·247850 :	—0·123114
·52	—0·368879	—0·073488	·72	—0·245384	—0·123546
·54	—0·367396	—0·074786	·74	—0·242909	—0·123966 :
·56	—0·365887 :	—0·076066	·76	—0·240425 :	—0·124375
·58	—0·364353 :	—0·077328	·78	—0·237934	—0·124772

Bessel-Clifford Functions of Zero and Unit Orders—contd.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
5·80	—0·235434 :	—0·125158	7·00	—0·078742 :	—0·130722 :
·82	—0·232927 :	—0·125533	·02	—0·076129 :	—0·130570 :
·84	—0·230413 :	—0·125896	·04	—0·073519 :	—0·130412 :
·86	—0·227892	—0·126248 :	·06	—0·070913	—0·130247 :
·88	—0·225363 :	—0·126590	·08	—0·068310	—0·130076
5·90	—0·222828 :	—0·126920 :	7·10	—0·065710	—0·129898 :
·92	—0·220286 :	—0·127240 :	·12	—0·063114	—0·129714 :
·94	—0·217738 :	—0·127549 :	·14	—0·060521 :	—0·129524 :
·96	—0·215185	—0·127847 :	·16	—0·057933	—0·129328
·98	—0·212625	—0·128135 :	·18	—0·055348 :	—0·129125 :
6·00	—0·210059 :	—0·128413	7·20	—0·052768	—0·128917
·02	—0·207488 :	—0·128680	·22	—0·050193	—0·128702 :
·04	—0·204912 :	—0·128936 :	·24	—0·047621	—0·128482
·06	—0·202331	—0·129183	·26	—0·045053 :	—0·128256
·08	—0·199745	—0·129419 :	·28	—0·042491	—0·128023 :
6·10	—0·197154 :	—0·129646	7·30	—0·039931 :	—0·127786
·12	—0·194559 :	—0·129862	·32	—0·037378 :	—0·127542 :
·14	—0·191960	—0·130068 :	·34	—0·034830	—0·127293
·16	—0·189356 :	—0·130265 :	·36	—0·032286 :	—0·127038 :
·18	—0·186749 :	—0·130452 :	·38	—0·029748 :	—0·126778 :
6·20	—0·184138 :	—0·130630	7·40	—0·027215 :	—0·126512 :
·22	—0·181524 :	—0·130797 :	·42	—0·024688	—0·126241 :
·24	—0·178906 :	—0·130956	·44	—0·022166	—0·125965
·26	—0·176286	—0·131105	·46	—0·019649 :	—0·125683 :
·28	—0·173662 :	—0·131245	·48	—0·017138 :	—0·125396 :
6·30	—0·171036 :	—0·131375 :	7·50	—0·014633 :	—0·125104 :
·32	—0·168407 :	—0·131496 :	·52	—0·012134 :	—0·124807 :
·34	—0·165776 :	—0·131609	·54	—0·009641 :	—0·124505 :
·36	—0·163143 :	—0·131712	·56	—0·007154 :	—0·124198
·38	—0·160508	—0·131806 :	·58	—0·004673 :	—0·123886
6·40	—0·157871	—0·131892	7·60	—0·002199	—0·123569
·42	—0·155232 :	—0·131969	·62	+0·000269 :	—0·123247
·44	—0·152592 :	—0·132037	·64	+0·002731	—0·122920 :
·46	—0·149951	—0·132096 :	·66	+0·005186	—0·122589 :
·48	—0·147308 :	—0·132147 :	·68	+0·007634 :	—0·122253 :
6·50	—0·144665	—0·132190 :	7·70	+0·010076	—0·121913
·52	—0·142021	—0·132224 :	·72	+0·012511	—0·121568
·54	—0·139376 :	—0·132250 :	·74	+0·014939	—0·121218
·56	—0·136731	—0·132268	·76	+0·017359 :	—0·120864
·58	—0·134085 :	—0·132277 :	·78	+0·019773 :	—0·120506
6·60	—0·131440	—0·132279	7·80	+0·022180	—0·120143
·62	—0·128794 :	—0·132272 :	·82	+0·024579	—0·119776
·64	—0·126149	—0·132258	·84	+0·026971	—0·119404 :
·66	—0·123504 :	—0·132236	·86	+0·029355	—0·119029
·68	—0·120860	—0·132205 :	·88	+0·031732	—0·118649 :
6·70	—0·118216	—0·132168	7·90	+0·034101	—0·118266
·72	—0·115573	—0·132122 :	·92	+0·036462 :	—0·117878
·74	—0·112931	—0·132069 :	·94	+0·038816 :	—0·117486 :
·76	—0·110290 :	—0·132009	·96	+0·041162	—0·117090 :
·78	—0·107651	—0·131941	·98	+0·043500	—0·116691
6·80	—0·105013	—0·131865 :	8·00	+0·045829 :	—0·116288
·82	—0·102376 :	—0·131783	·02	+0·048151 :	—0·115880 :
·84	—0·099741 :	—0·131693	·04	+0·050465	—0·115469 :
·86	—0·097108 :	—0·131596	·06	+0·052770	—0·115055
·88	—0·094478	—0·131492	·08	+0·055067	—0·114637
6·90	—0·091849	—0·131381	8·10	+0·057355 :	—0·114215
·92	—0·089222 :	—0·131263	·12	+0·059635 :	—0·113789 :
·94	—0·086598 :	—0·131138	·14	+0·061907	—0·113360 :
·96	—0·083977	—0·131006	·16	+0·064170	—0·112928
·98	—0·081358 :	—0·130867 :	·18	+0·066424	—0·112492 :

Bessel-Clifford Functions of Zero and Unit Orders—contd.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
8·20	+0·068669 :	—0·112053 :	9·40	+0·185337	—0·081139
·22	+0·070906 :	—0·111611	·42	+0·186954	—0·080571 :
·24	+0·073134	—0·111165	·44	+0·188559 :	—0·080003
·26	+0·075353	—0·110716	·46	+0·190154	—0·079433 :
·28	+0·077562 :	—0·110264	·48	+0·191737	—0·078863
8·30	+0·079763 :	—0·109809	9·50	+0·193308 :	—0·078292
·32	+0·081955	—0·109350 :	·52	+0·194868 :	—0·077719 :
·34	+0·084137 :	—0·108889	·54	+0·196417 :	—0·077146 :
·36	+0·086310 :	—0·108425	·56	+0·197954 :	—0·076572 :
·38	+0·088474 :	—0·107957 :	·58	+0·199480	—0·075998
8·40	+0·090629	—0·107487 :	9·60	+0·200994 :	—0·075422 :
·42	+0·092774	—0·107014	·62	+0·202497	—0·074846
·44	+0·094909 :	—0·106538	·64	+0·203988 :	—0·074269
·46	+0·097035 :	—0·106059 :	·66	+0·205468	—0·073691 :
·48	+0·099152	—0·105578	·68	+0·206936	—0·073113 :
8·50	+0·101258 :	—0·105093 :	9·70	+0·208392 :	—0·072534 :
·52	+0·103355 :	—0·104607	·72	+0·209837 :	—0·071955
·54	+0·105442 :	—0·104117 :	·74	+0·211270 :	—0·071374 :
·56	+0·107520	—0·103625	·76	+0·212692 :	—0·070794
·58	+0·109587 :	—0·103130 :	·78	+0·214102 :	—0·070213
8·60	+0·111645 :	—0·102633 :	9·80	+0·215501	—0·069631 :
·62	+0·113693	—0·102134	·82	+0·216887 :	—0·069049
·64	+0·115730 :	—0·101632	·84	+0·218263	—0·068466 :
·66	+0·117758 :	—0·101127 :	·86	+0·219626 :	—0·067883 :
·68	+0·119776	—0·100621	·88	+0·220978	—0·067300
8·70	+0·121783	—0·100112	9·90	+0·222318 :	—0·066716 :
·72	+0·123780 :	—0·099601	·92	+0·223647	—0·066132 :
·74	+0·125767	—0·099087 :	·94	+0·224963 :	—0·065548
·76	+0·127744	—0·098572	·96	+0·226268 :	—0·064963 :
·78	+0·129710	—0·098054	·98	+0·227562	—0·064378 :
8·80	+0·131666	—0·097534	10·00	+0·228844	—0·063793
·82	+0·133611 :	—0·097012	·02	+0·230114	—0·063208
·84	+0·135546 :	—0·096488	·04	+0·231372	—0·062622 :
·86	+0·137471	—0·095962 :	·06	+0·232618 :	—0·062036 :
·88	+0·139385	—0·095434 :	·08	+0·233853 :	—0·061450 :
8·90	+0·141288 :	—0·094904 :	10·10	+0·235076 :	—0·060864 :
·92	+0·143181	—0·094373	·12	+0·236288	—0·060278 :
·94	+0·145063	—0·093839 :	·14	+0·237488	—0·059692 :
·96	+0·146934 :	—0·093304	·16	+0·238676	—0·059106 :
·98	+0·148795 :	—0·092767	·18	+0·239852	—0·058520
9·00	+0·150645 :	—0·092228	10·20	+0·241016 :	—0·057934
·02	+0·152484 :	—0·091687 :	·22	+0·242169 :	—0·057348
·04	+0·154312 :	—0·091145	·24	+0·243310 :	—0·056761 :
·06	+0·156130	—0·090601 :	·26	+0·244440	—0·056175 :
·08	+0·157937	—0·090056	·28	+0·245557 :	—0·055589 :
9·10	+0·159732 :	—0·089509	10·30	+0·246663 :	—0·055004
·12	+0·161517	—0·088960 :	·32	+0·247758	—0·054418
·14	+0·163291	—0·088410 :	·34	+0·248840 :	—0·053832 :
·16	+0·165053 :	—0·087859	·36	+0·249911	—0·053247 :
·18	+0·166805	—0·087306	·38	+0·250970	—0·052662
9·20	+0·168546	—0·086751 :	10·40	+0·252017 :	—0·052077 :
·22	+0·170275	—0·086196	·42	+0·253053 :	—0·051492 :
·24	+0·171993 :	—0·085639	·44	+0·254077 :	—0·050908
·26	+0·173701	—0·085080 :	·46	+0·255089 :	—0·050324
·28	+0·175397	—0·084521	·48	+0·256090 :	—0·049740 :
9·30	+0·177081 :	—0·083960 :	10·50	+0·257079	—0·049157
·32	+0·178755	—0·083398 :	·52	+0·258056 :	—0·048573 :
·34	+0·180417 :	—0·082835	·54	+0·259022	—0·047991
·36	+0·182068 :	—0·082271	·56	+0·259976	—0·047408 :
·38	+0·183708 :	—0·081705 :	·58	+0·260918 :	—0·046826 :

Bessel-Clifford Functions of Zero and Unit Orders—contd.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
10·60	+0·261849	—0·046245	11·80	+0·296928 :	—0·012789
·62	+0·262768 :	—0·045664	·82	+0·297179	—0·012264 :
·64	+0·263676	—0·045083 :	·84	+0·297419	—0·011742
·66	+0·264571 :	—0·044503	·86	+0·297648 :	—0·011220 :
·68	+0·265456	—0·043923 :	·88	+0·297868	—0·010700
10·70	+0·266328 :	—0·043344 :	11·90	+0·298076 :	—0·010181 :
·72	+0·267189 :	—0·042766	·92	+0·298275	—0·009664
·74	+0·268039 :	—0·042188	·94	+0·298463	—0·009148
·76	+0·268877	—0·041610 :	·96	+0·298641	—0·008633 :
·78	+0·269703 :	—0·041034	·98	+0·298808 :	—0·008120
10·80	+0·270518 :	—0·040457 :	12·00	+0·298966	—0·007608 :
·82	+0·271322	—0·039882	·02	+0·299113	—0·007098 :
·84	+0·272114	—0·039307	·04	+0·299250	—0·006589 :
·86	+0·272894 :	—0·038733	·06	+0·299376 :	—0·006082 :
·88	+0·273663	—0·038159 :	·08	+0·299493	—0·005576 :
10·90	+0·274420 :	—0·037586 :	12·10	+0·299599 :	—0·005072
·92	+0·275166 :	—0·037014 :	·12	+0·299696	—0·004569 :
·94	+0·275901	—0·036443	·14	+0·299782 :	—0·004068
·96	+0·276624 :	—0·035872 :	·16	+0·299858 :	—0·003568
·98	+0·277336	—0·035302 :	·18	+0·299925	—0·003070
11·00	+0·278036 :	—0·034733 :	12·20	+0·299981 :	—0·002573
·02	+0·278725 :	—0·034165	·22	+0·300028	—0·002078
·04	+0·279403	—0·033597 :	·24	+0·300064 :	—0·001584
·06	+0·280069 :	—0·033031	·26	+0·300091 :	—0·001092
·08	+0·280724 :	—0·032465 :	·28	+0·300108 :	—0·000601 :
11·10	+0·281368	—0·031900 :	12·30	+0·300115 :	—0·000112 :
·12	+0·282000 :	—0·031336 :	·32	+0·300113	+0·000375
·14	+0·282621 :	—0·030773 :	·34	+0·300100 :	+0·000860 :
·16	+0·283231 :	—0·030211	·36	+0·300078 :	+0·001345
·18	+0·283830	—0·029650	·38	+0·300046 :	+0·001827 :
11·20	+0·284417 :	—0·029089 :	12·40	+0·300005 :	+0·002308 :
·22	+0·284993 :	—0·028530	·42	+0·299954 :	+0·002787 :
·24	+0·285558 :	—0·027972	·44	+0·299894	+0·003265 :
·26	+0·286112 :	—0·027414 :	·46	+0·299824	+0·003741 :
·28	+0·286655	—0·026858	·48	+0·299744	+0·004216
11·30	+0·287186 :	—0·026302 :	12·50	+0·299655	+0·004688 :
·32	+0·287707	—0·025748 :	·52	+0·299556 :	+0·005159 :
·34	+0·288216 :	—0·025195	·54	+0·299449	+0·005629
·36	+0·288715	—0·024643	·56	+0·299331 :	+0·006097
·38	+0·289202 :	—0·024091 :	·58	+0·299205	+0·006563
11·40	+0·289678 :	—0·023541 :	12·60	+0·299069	+0·007027 :
·42	+0·290144	—0·022992 :	·62	+0·298924	+0·007490
·44	+0·290598 :	—0·022445	·64	+0·298769 :	+0·007951
·46	+0·291042	—0·021898	·66	+0·298606	+0·008410 :
·48	+0·291474 :	—0·021352 :	·68	+0·298433	+0·008868
11·50	+0·291896	—0·020808	12·70	+0·298251	+0·009324
·52	+0·292306 :	—0·020265	·72	+0·298060	+0·009778
·54	+0·292706 :	—0·019723	·74	+0·297860	+0·010230 :
·56	+0·293095 :	—0·019182	·76	+0·297651	+0·010681
·58	+0·293474	—0·018642 :	·78	+0·297432 :	+0·011130
11·60	+0·293841 :	—0·018104	12·80	+0·297205 :	+0·011577 :
·62	+0·294198	—0·017566 :	·82	+0·296969 :	+0·012022 :
·64	+0·294544	—0·017030 :	·84	+0·296725	+0·012466 :
·66	+0·294879	—0·016496	·86	+0·296471	+0·012908
·68	+0·295204	—0·015962 :	·88	+0·296208 :	+0·013348 :
11·70	+0·295517 :	—0·015430 :	12·90	+0·295937	+0·013786 :
·72	+0·295821	—0·014899 :	·92	+0·295657	+0·014223
·74	+0·296113 :	—0·014370	·94	+0·295368	+0·014658
·76	+0·296396	—0·013841 :	·96	+0·295070 :	+0·015091
·78	+0·296667 :	—0·013314 :	·98	+0·294764 :	+0·015522

Bessel-Clifford Functions of Zero and Unit Orders—contd.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
13·00	+0·294450	+0·015951 :	14·20	+0·261228	+0·038271 :
·02	+0·294126 :	+0·016379	·22	+0·260459 :	+0·038584 :
·04	+0·293794 :	+0·016804 :	·24	+0·259684 :	+0·038896
·06	+0·293454 :	+0·017228 :	·26	+0·258903 :	+0·039205
·08	+0·293105 :	+0·017650 :	·28	+0·258116 :	+0·039512
13·10	+0·292748 :	+0·018071	14·30	+0·257323	+0·039817
·12	+0·292382 :	+0·018489 :	·32	+0·256523 :	+0·040120 :
·14	+0·292008 :	+0·018906	·34	+0·255718	+0·040421 :
·16	+0·291626 :	+0·019321	·36	+0·254907	+0·040721
·18	+0·291236	+0·019733 :	·38	+0·254089 :	+0·041018
13·20	+0·290837	+0·020145	14·40	+0·253266	+0·041313 :
·22	+0·290430	+0·020554	·42	+0·252437	+0·041607
·24	+0·290015	+0·020961 :	·44	+0·251602	+0·041898 :
·26	+0·289591 :	+0·021367	·46	+0·250761	+0·042188
·28	+0·289160 :	+0·021770 :	·48	+0·249914 :	+0·042475 :
13·30	+0·288721	+0·022172 :	14·50	+0·249062	+0·042761
·32	+0·288273 :	+0·022572	·52	+0·248204	+0·043044 :
·34	+0·287818	+0·022970	·54	+0·247340	+0·043326
·36	+0·287354 :	+0·023366 :	·56	+0·246471	+0·043605 :
·38	+0·286883 :	+0·023760 :	·58	+0·245596	+0·043883 :
13·40	+0·286404	+0·024153	14·60	+0·244715 :	+0·044159
·42	+0·285917 :	+0·024543 :	·62	+0·243829 :	+0·044433
·44	+0·285422 :	+0·024932	·64	+0·242938 :	+0·044704 :
·46	+0·284920	+0·025318 :	·66	+0·242041 :	+0·044974 :
·48	+0·284410	+0·025703 :	·68	+0·241139 :	+0·045242 :
13·50	+0·283892	+0·026086 :	14·70	+0·240232	+0·045508
·52	+0·283366 :	+0·026467 :	·72	+0·239319	+0·045772
·54	+0·282833	+0·026846 :	·74	+0·238401	+0·046034
·56	+0·282292 :	+0·027223 :	·76	+0·237477 :	+0·046294
·58	+0·281744 :	+0·027599	·78	+0·236549	+0·046552 :
13·60	+0·281188 :	+0·027972	14·80	+0·235615 :	+0·046808 :
·62	+0·280625 :	+0·028343 :	·82	+0·234677	+0·047062 :
·64	+0·280055	+0·028713	·84	+0·233733	+0·047315
·66	+0·279477	+0·029080 :	·86	+0·232784 :	+0·047565
·68	+0·278891 :	+0·029446 :	·88	+0·231830 :	+0·047813 :
13·70	+0·278299	+0·029810	14·90	+0·230871 :	+0·048060
·72	+0·277699	+0·030172	·92	+0·229908	+0·048304
·74	+0·277092	+0·030531 :	·94	+0·228939 :	+0·048546 :
·76	+0·276478	+0·030889 :	·96	+0·227966	+0·048787
·78	+0·275856 :	+0·031245 :	·98	+0·226988	+0·049025 :
13·80	+0·275228	+0·031599 :	15·00	+0·226005	+0·049262 :
·82	+0·274592 :	+0·031952	·02	+0·225017 :	+0·049497
·84	+0·273950	+0·032302	·04	+0·224025 :	+0·049730
·86	+0·273300 :	+0·032650	·06	+0·223028 :	+0·049960 :
·88	+0·272644	+0·032996 :	·08	+0·222027	+0·050189 :
13·90	+0·271980 :	+0·033341	15·10	+0·221021	+0·050416 :
·92	+0·271310 :	+0·033683	·12	+0·220010 :	+0·050641 :
·94	+0·270633 :	+0·034023 :	·14	+0·218995	+0·050864 :
·96	+0·269949 :	+0·034362	·16	+0·217975 :	+0·051085 :
·98	+0·269259	+0·034698 :	·18	+0·216952	+0·051304 :
14·00	+0·268561 :	+0·035033	15·20	+0·215923 :	+0·051522
·02	+0·267857 :	+0·035366	·22	+0·214891	+0·051737 :
·04	+0·267147	+0·035696 :	·24	+0·213854	+0·051950 :
·06	+0·266430	+0·036025 :	·26	+0·212813	+0·052162
·08	+0·265706	+0·036352	·28	+0·211767 :	+0·052372
14·10	+0·264975 :	+0·036677	15·30	+0·210718	+0·052579 :
·12	+0·264239	+0·037000	·32	+0·209664 :	+0·052785 :
·14	+0·263495 :	+0·037320 :	·34	+0·208606 :	+0·052989 :
·16	+0·262746	+0·037639 :	·36	+0·207545	+0·053191
·18	+0·261990	+0·037956 :	·38	+0·206479	+0·053391

Bessel-Clifford Functions of Zero and Unit Orders—contd.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
15·40	+0·205409	+0·053589 :	16·60	+0·135345 :	+0·062093
·42	+0·204335 :	+0·053785 :	·62	+0·134103	+0·062180 :
·44	+0·203258	+0·053980	·64	+0·132858 :	+0·062266 :
·46	+0·202176 :	+0·054172	·66	+0·131612	+0·062350 :
·48	+0·201091	+0·054362 :	·68	+0·130364 :	+0·062432 :
15·50	+0·200002	+0·054551 :	16·70	+0·129115	+0·062513
·52	+0·198909	+0·054738	·72	+0·127864	+0·062592
·54	+0·197812 :	+0·054923	·74	+0·126511 :	+0·062669 :
·56	+0·196712	+0·055106	·76	+0·125357	+0·062745
·58	+0·195608	+0·055287	·78	+0·124101 :	+0·062819
15·60	+0·194500 :	+0·055466	16·80	+0·122844 :	+0·062891
·62	+0·193389 :	+0·055643 :	·82	+0·121586	+0·062961 :
·64	+0·192275	+0·055819	·84	+0·120326	+0·063030 :
·66	+0·191156 :	+0·055992 :	·86	+0·119064 :	+0·063097 :
·68	+0·190035	+0·056164	·88	+0·117802	+0·063163
15·70	+0·188910	+0·056334	16·90	+0·116538	+0·063227
·72	+0·187782	+0·056502	·92	+0·115273	+0·063289 :
·74	+0·186650	+0·056668	·94	+0·114006 :	+0·063350
·76	+0·185515	+0·056832	·96	+0·112739	+0·063409
·78	+0·184377	+0·056994 :	·98	+0·111470	+0·063466 :
15·80	+0·183235 :	+0·057155	17·00	+0·110200 :	+0·063522
·82	+0·182090 :	+0·057314	·02	+0·108929 :	+0·063576
·84	+0·180943	+0·057470 :	·04	+0·107657 :	+0·063628 :
·86	+0·179792	+0·057625 :	·06	+0·106384	+0·063679 :
·88	+0·178637 :	+0·057779	·08	+0·105110	+0·063728 :
15·90	+0·177480 :	+0·057930	17·10	+0·103835	+0·063776 :
·92	+0·176320 :	+0·058079 :	·12	+0·102559	+0·063822 :
·94	+0·175157 :	+0·058227	·14	+0·101282	+0·063867
·96	+0·173991 :	+0·058373	·16	+0·100004 :	+0·063910
·98	+0·172822 :	+0·058517	·18	+0·098726	+0·063951
16·00	+0·171651	+0·058659	17·20	+0·097446 :	+0·063991
·02	+0·170476	+0·058799 :	·22	+0·096166	+0·064029
·04	+0·169299	+0·058938	·24	+0·094885	+0·064065 :
·06	+0·168118 :	+0·059074 :	·26	+0·093603 :	+0·064100 :
·08	+0·166936	+0·059209 :	·28	+0·092321	+0·064134
16·10	+0·165750 :	+0·059342 :	17·30	+0·091038	+0·064165 :
·12	+0·164562	+0·059474	·32	+0·089754 :	+0·064196
·14	+0·163371 :	+0·059603 :	·34	+0·088470 :	+0·064224 :
·16	+0·162178	+0·059731	·36	+0·087185 :	+0·064252
·18	+0·160982	+0·059857	·38	+0·085900 :	+0·064277 :
16·20	+0·159784	+0·059981	17·40	+0·084614 :	+0·064301 :
·22	+0·158583	+0·060103 :	·42	+0·083328 :	+0·064324 :
·24	+0·157379 :	+0·060224	·44	+0·082041 :	+0·064345 :
·26	+0·156174	+0·060342 :	·46	+0·080754 :	+0·064365
·28	+0·154966	+0·060459 :	·48	+0·079467	+0·064383
16·30	+0·153755 :	+0·060575	17·50	+0·078179	+0·064399 :
·32	+0·152543	+0·060688 :	·52	+0·076891	+0·064414 :
·34	+0·151328	+0·060800	·54	+0·075602 :	+0·064428
·36	+0·150111	+0·060910	·56	+0·074314	+0·064440
·38	+0·148891 :	+0·061018	·58	+0·073025	+0·064450 :
16·40	+0·147670 :	+0·061124 :	17·60	+0·071736	+0·064459 :
·42	+0·146446 :	+0·061229 :	·62	+0·070446 :	+0·064467
·44	+0·145221	+0·061332	·64	+0·069157 :	+0·064473
·46	+0·143993 :	+0·061433 :	·66	+0·067868	+0·064477 :
·48	+0·142764	+0·061533	·68	+0·066578	+0·064480 :
16·50	+0·141532	+0·061630 :	17·70	+0·065288 :	+0·064482
·52	+0·140298 :	+0·061726 :	·72	+0·063999	+0·064482 :
·54	+0·139063	+0·061820 :	·74	+0·062709 :	+0·064481
·56	+0·137826	+0·061913	·76	+0·061419 :	+0·064478 :
·58	+0·136586 :	+0·062004	·78	+0·060130	+0·064474 :

Bessel-Clifford Functions of Zero and Unit Orders—contd.

x	$C_0(x)$	$C_1(x)$	x	$C_0(x)$	$C_1(x)$
17·80	+0·058840 :	+0·064468 :	18·90	−0·011126 :	+0·062092 :
·82	+0·057551 :	+0·064461 :	·92	−0·012367 :	+0·062014
·84	+0·056262	+0·064453	·94	−0·013607	+0·061935
·86	+0·054973 :	+0·064443 :	·96	−0·014845	+0·061854 :
·88	+0·053684 :	+0·064432	·98	−0·016081 :	+0·061773
17·90	+0·052396	+0·064419 :	19·00	−0·017316	+0·061690 :
·92	+0·051108	+0·064405	·02	−0·018549	+0·061607
·94	+0·049820	+0·064389 :	·04	−0·019780 :	+0·061522
·96	+0·048532	+0·064372 :	·06	−0·021010	+0·061436
·98	+0·047245	+0·064354 :	·08	−0·022237 :	+0·061349
18·00	+0·045958	+0·064334 :	19·10	−0·023464	+0·061261
·02	+0·044671 :	+0·064313 :	·12	−0·024688	+0·061171 :
·04	+0·043385 :	+0·064291	·14	−0·025910 :	+0·061081
·06	+0·042100	+0·064267	·16	−0·027131 :	+0·060990
·08	+0·040815	+0·064242	·18	−0·028350 :	+0·060897 :
18·10	+0·039530 :	+0·064215 :	19·20	−0·029567 :	+0·060803 :
·12	+0·038246	+0·064187 :	·22	−0·030782 :	+0·060709
·14	+0·036963	+0·064158	·24	−0·031995 :	+0·060613 :
·16	+0·035680	+0·064127 :	·26	−0·033207	+0·060516 :
·18	+0·034397 :	+0·064095 :	·28	−0·034416 :	+0·060418 :
18·20	+0·033116	+0·064062	19·30	−0·035623 :	+0·060319 :
·22	+0·031835	+0·064027 :	·32	−0·036829	+0·060220
·24	+0·030555	+0·063991 :	·34	−0·038032 :	+0·060119
·26	+0·029275 :	+0·063954	·36	−0·039234	+0·060017
·28	+0·027997	+0·063915 :	·38	−0·040433	+0·059913 :
18·30	+0·026719	+0·063875 :	19·40	−0·041630 :	+0·059809 :
·32	+0·025442	+0·063834	·42	−0·042825 :	+0·059704 :
·34	+0·024165 :	+0·063791 :	·44	−0·044018 :	+0·059598 :
·36	+0·022890	+0·063747 :	·46	−0·045209 :	+0·059491 :
·38	+0·021615 :	+0·063702 :	·48	−0·046398	+0·059383 :
18·40	+0·020342	+0·063656	19·50	−0·047584 :	+0·059274
·42	+0·019069 :	+0·063608 :	·52	−0·048769	+0·059164
·44	+0·017798	+0·063559 :	·54	−0·049951 :	+0·059053
·46	+0·016527	+0·063509	·56	−0·051131	+0·058941
·48	+0·015257 :	+0·063457 :	·58	−0·052309	+0·058828
18·50	+0·013989	+0·063405	19·60	−0·053484 :	+0·058714
·52	+0·012721 :	+0·063350 :	·62	−0·054657 :	+0·058599
·54	+0·011455	+0·063295 :	·64	−0·055828 :	+0·058483
·56	+0·010189 :	+0·063239	·66	−0·056997	+0·058366
·58	+0·008925	+0·063181	·68	−0·058163	+0·058248
18·60	+0·007662	+0·063122	19·70	−0·059326 :	+0·058129 :
·62	+0·006400 :	+0·063062	·72	−0·060488	+0·058009 :
·64	+0·005139 :	+0·063000 :	·74	−0·061647	+0·057889
·66	+0·003880 :	+0·062937 :	·76	−0·062803 :	+0·057767 :
·68	+0·002622	+0·062874	·78	−0·063958	+0·057645
18·70	+0·001365 :	+0·062808 :	19·80	−0·065109 :	+0·057521 :
·72	+0·000110	+0·062742 :	·82	−0·066258 :	+0·057397 :
·74	−0·001144 :	+0·062675	·84	−0·067405 :	+0·057272
·76	−0·002397	+0·062606	·86	−0·068549 :	+0·057146
·78	−0·003648 :	+0·062536 :	·88	−0·069691	+0·057019
18·80	−0·004898 :	+0·062465	19·90	−0·070830 :	+0·056891
·82	−0·006147	+0·062393	·92	−0·071967	+0·056762
·84	−0·007394	+0·062319 :	·94	−0·073101	+0·056632 :
·86	−0·008640	+0·062245	·96	−0·074232	+0·056502
·88	−0·009884	+0·062169	·98	−0·075361	+0·056370 :
			20·00	−0·076487	+0·056238

Solar Observatory in Australia.—*Final Report of Committee* (Prof. H. H. TURNER, *Chairman*; Dr. W. G. DUFFIELD, *Secretary*; Rev. A. L. CORTIE, Dr. W. J. S. LOCKYER, Mr. F. McLEAN, Sir A. SCHUSTER) *appointed to aid the work of establishing an Observatory.* (*Drawn up by the Secretary.*)

IN September 1922 the Secretary paid another visit to Australia, but the General Elections which followed his arrival, and the rearrangement of the political parties in Australia, precluded any attempt to approach the Federal Cabinet before Easter 1923. A memorandum was prepared setting forth the history of the movement since its inception in 1907, and the measure of support accorded to it by the various Ministries before whom the project has been brought.

This memorandum was presented to the Rt. Hon. Senator Pearce, P.C., Minister for the Department of Home and Territories in the Commonwealth Government, and further information was provided by the Secretary in the course of an interview.

Senator Pearce gave his own warm support and promised to bring the matter before the Cabinet. This body subsequently agreed to the proposals which had been made. These were briefly as follows :—

(1) SITE.—*The provision of a site upon Mt. Stromlo, about* 7 *miles from the Federal Capital City, Canberra.*

This site had been tested by photographic and visual observations made under the ægis of Mr. Baracchi over a period of 15 months, with a 9-inch refractor and a 3½-inch camera lens, and reported upon very favourably.

The site is already furnished with a road to the summit, 2,600 feet above sea-level, or 600 feet above the level of Canberra.

A water supply is assured, because the pipe-head reservoir providing the city with water is situated upon Mt. Stromlo about 100 feet below the summit.

Electric energy is also available for light and power; the transmission lines from the central electric power station pass about half a mile from the site of the Observatory.

(2) EQUIPMENT.—*The provision of a sum of* £3,500 *for the purchase of equipment during the first year, July* 1923–*July* 1924.

In addition to this sum, it may be noted that a sum of over £1,500 has been subscribed by supporters of the movement. Towards this the British Association contribution is £50.

There was also at that time the following equipment: (*a*) a 9-inch Grubb refractor presented by Mr. James Oddie, and mounted upon Mt. Stromlo in a building consisting of a dome and four small rooms. This instrument is furnished with a prominence spectroscope, and an excellent battery of eyepieces, etc.

(*b*) A 6-inch Grubb refractor, presented by the Trustees of the Estate of the late Lord Farnham. This is at present housed at Melbourne Observatory.

(3) ANNUAL UPKEEP.—*The provision of a sum of* £3,500 *for the upkeep for the first year,* 1923–1924.

This sum was to be devoted to the provision of a Staff consisting of the following: Director, First Assistant, Second Assistant, Research Fellow, Mechanic, Apparatus Mechanic.

(4) HOUSING.—*The provision of laboratories, offices, library, observatory buildings, and houses for the staff.*

After consultation with Senator Pearce, it was decided that the first step towards the establishment of the Observatory should be the appointment of the Director, and the Commonwealth Cabinet subsequently invited the Astronomer Royal and Professor Turner to act upon the selection committee. The recommendation which was made by these gentlemen after consultation with Professor Newall and Professor Fowler was ultimately adopted by the Government.

Before leaving Australia Mt. Stromlo was visited by the Director-General of Works for the Commonwealth (Colonel Owen) and Professor Duffield, and the general lay-out of the Observatory site provisionally agreed upon.

During the past six months progress has been made in selecting apparatus and in appointing assistants.

The Director is fortunately able to report a notable gift to the Observatory by Mr. J. H. Reynolds, of Birmingham, who has presented to the Observatory a 30-inch reflecting telescope, similar to the instrument he had previously given to the Egyptian Observatory at Helwan. This is being adapted for the latitude of Canberra and is being otherwise put into perfect condition.

To him and to the other donors of apparatus and money who have been named in previous reports the Committee extend their very grateful thanks. The successful issue has been due not only to the scientific evidence and to the generous outlay of time expended upon the scheme by those who have attended deputations and have in other ways assisted, but also to the recognition by the Government of Australia that there must be virtue in a project which has been so warmly supported by individual generosity.

The labours of the Committee may now cease.

Characteristic Fossils.—*Final Report of Committee* (Prof. P. F. KENDALL, *Chairman*; Mr. H. C. VERSEY, *Secretary*; Prof. W. S. BOULTON, Dr. A. R. DWERRYHOUSE, Prof. J. W. GREGORY, Sir T. H. HOLLAND, Prof. S. H. REYNOLDS, Dr. MARIE STOPES, Profs. J. E. MARR *and* W. W. WATTS, Mr. H. WOODS, *and* Sir A. SMITH WOODWARD) *appointed to consider the preparation of a list of characteristic fossils. (Compiled by the Secretary.)*

THE progress made by the Committee in the first years of its formation was stopped by the death of the then Hon. Secretary, the Rev. W. L. Carter. Many of the MS. suggestions and printed lists accumulated by him were lost. From those recovered, lists were prepared showing the varying opinions of the authorities consulted, and were circulated among all members of the Committee, among other teachers of Geology and among other specialists in special branches of Palæontology. From the replies received, a final list has been prepared which represents, as far as possible, the majority opinion of the Committee.

The definition of a Characteristic Fossil adopted by the Committee is as follows :—

> 1. DEFINITION.—' A characteristic fossil is one, either genus or species, that is restricted to a particular horizon, or is abundant at the horizon and comparatively rare elsewhere, so that its presence in a bed would raise a clear presumption of the stratigraphical position or age of the bed.'

The list is divided into three grades :

(*a*) List ' A,' comprising about 200 species suitable for elementary students.

(*b*) List ' B,' about 200 species suitable for Final students in addition to List A.

(*c*) List ' C,' about 200 species suitable for Honours students in addition to Lists A and B.

The Committee is not unanimous on the advisability of fixing a ' C ' list, but suggests the one chosen as a suitable nucleus which may be modified at the teacher's discretion, according to special or local requirements. It suggests that the use of the newer generic or sub-generic names is also a matter for the individual teacher to decide.

A number of foreign species have been introduced when British representatives of the periods in question are lacking. The Committee recommends that the list, which is appended, be printed as follows :—

(*a*) As an integral part of the Annual Report.

(*b*) Free reprints of this be issued to the teachers of Geology in the country.

(*c*) As a special publication, available for students and others at a small cost.

The thanks of the Committee are due to the following authorities who have kindly helped during the past two years :—

Professors Cox, Hawkins, Hickling, Jehu, Seward, Sollas, Drs. Bather, Kidston.

CAMBRIAN.

Lower Cambrian.

BC	Kutorgina cingulata	Brachiopoda
ABC	Olenellus sp.	Trilobita
C	Salterella sp.	Vermes

Middle Cambrian.

BC	Protospongia fenestrata	Porifera
BC	Agnostus fissus	Trilobita
ABC	Paradoxides davidis	,,
C	Conocoryphe sulzeri	,,
BC	Microdiscus punctatus	,,

Upper Cambrian (Olenus fauna).

ABC	Lingulella davisi	Brachiopoda
C	Orthis lenticularis	,,
ABC	Olenus sp.	Trilobita
BC	Agnostus pisiformis	,,
BC	Parabolina spinulosa	,,
BC	Hymenocaris vermicauda	Phyllocarida

Upper Cambrian (Tremadocian).

ABC	Dictyograptus socialis	Graptoloidea
C	Hyolithus operculatus	Mollusca
ABC	Angelina sedgwicki	Trilobita
ABC	Asaphellus homfrayi	,,
BC	Shumardia pusilla	,,

ORDOVICIAN.

Arenigian.

ABC	Didymograptus extensus	Graptoloidea
C	,, hirundo	,,
ABC	Phyllograptus sp.	,,
ABC	Tetragraptus sp.	,,
C	Orthis carausi	Brachiopoda
C	Calymene tristani	Trilobita
BC	Ogygia selwyni	,,

Llanvirnian.

ABC	Didymograptus murchisoni	Graptoloidea
BC	,, bifidus	,,
BC	Ampyx nudus	Trilobita
C	Æglina binodosa	,,

Llandeilian.

ABC	Nemagraptus gracilis	Graptoloidea
C	Climacograptus bicornis	,,
C	Dicranograptus ziczac	,,
C	Diplograptus (Orthograptus) teretiusculus	,,
ABC	Ogygia buchi	Trilobita
ABC	Asaphus tyrannus	,,
BC	Trinucleus fimbriatus	,,

Caradocian.

BC	Diplograptus calcaratus	Graptoloidea
ABC	Dicranograptus ramosus	,,
C	Pleurograptus linearis	,,
ABC	Orthis actoniæ	Brachiopoda
BC	,, calligramma	,,
C	Strophomena expansa	,,
C	Leptæna sericea	,,
ABC	Trinucleus concentricus	Trilobita
BC	Calymene senaria	,,

Ashgillian.

C	Dicellograptus anceps	Graptoloidea
C	Orthograptus truncatus	,,
C	Echinosphærites arachnoideus	Cystidea
ABC	Tentaculites anglicus	Mollusca
BC	Illænus bowmanni	Trilobita
BC	Staurocephalus sp.	,,
ABC	Phillipsinella parabola	,,

SILURIAN.

Valentian (Lower).

C	Climacograptus normalis	Graptoloidea
C	Diplograptus (Orthograptus) vesiculosus	,,
BC	Pentamerus undatus	Brachiopoda
ABC	Stricklandinia lens	,,

Valentian (Upper).

ABC	Monograptus gregarius	Graptoloidea
C	,, turriculatus	,,
C	,, sedgwicki	,,
ABC	Rastrites peregrinus	,,
ABC	Pentamerus oblongus	Brachiopoda
BC	Meristina crassa	,,

Salopian (Wenlock Shale).

ABC	Monograptus priodon	Graptoloidea
BC	Cyrtograptus murchisoni	,,
BC	Cardiola interrupta	Pelecypoda
ABC	Orthis elegantula	Brachiopoda
BC	,, biloba	,,
C	Orthoceras annulatum	Cephalopoda

Salopian (Wenlock Limestone).

ABC	Favosites gothlandica	Anthozoa
BC	Heliolites megastoma	,,
ABC	Halysites catenularia	,,
BC	Acervularia luxurians	,,
ABC	Omphyma subturbinatum	,,
C	Crotalocrinus sp.	Crinoidea
ABC	Atrypa reticularis	Brachiopoda
ABC	Strophonella euglypha	,,
BC	Pentamerus galeatus	,,
ABC	Leptæna rhomboidalis	,,
ABC	Horiostoma rugosa	Gastropoda
BC	Trimerus delphinocephalus	Trilobita
ABC	Calymene blumenbachi	,,
ABC	Phacops caudatus	,,

Salopian (Lower Ludlow).

ABC	Monograptus colonus	Graptoloidea
BC	Gomphoceras ellipticum	Cephalopoda
C	Acidaspis coronata	Trilobita

Salopian (Aymestry Limestone).

ABC	Conchidium knighti	Brachiopoda
BC	Dayia navicula	,,

Downtonian.

BC	Lingula cornea	Brachiopoda
ABC	Chonetes striatella	,,
BC	Camarotoechia nucula	,,
ABC	Pterinea danbyi	Pelecypoda
C	Orthoceras bullatum	Cephalopoda
C	Cornulites serpularius	Vermes
BC	Thelodus sp.	Pisces (Ostracodermi)

DEVONIAN (Marine).

Lower.

ABC	Pleurodictyum problematicum	Anthozoa
BC	Spirifer primævus	Brachiopoda
C	Bellerophon trilobatus	Gastropoda
BC	Homalonotus armatus	Trilobita

Middle.

BC	Stromatopora sp.	Hydrozoa
ABC	Calceola sandalina	Anthozoa
ABC	Heliolites porosus	,,
BC	Pachypora cervicornis	,,
ABC	Stringocephalus burtini	Brachiopoda
C	Spirifer undiferus	,,
BC	Uncites gryphus	,,
C	Mœneceras sp.	Cephalopoda

Upper.

ABC	Acervularia pentagona	Anthozoa
C	Phillipsastræa pengellyi	,,
C	Cyathophyllum cæspitosum	,,
BC	Rhynchonella cuboides	Brachiopoda
ABC	Spirifer verneuili	,,
BC	Cucullæa trapezium	Pelecypoda
ABC	Clymenia sp.	Cephalopoda
C	Anarcestes sp.	,,
BC	Entomis serrato-striata	Ostracoda

DEVONIAN (Old Red Sandstone).

Lower.

BC	Eurypterus anglicus	Merostomata
C	Pterygotus anglicus	,,
ABC	Cephalaspis lyelli	Ostracodermi
C	Pteraspis rostratus	,,
C	Parka decipiens	Plantæ
ABC	Psilophyton princeps	,,

Middle.

C	Pterichthys sp.	Ostracodermi
ABC	Coccosteus decipiens	Pisces
BC	Osteolepis sp.	,,
C	Cheirolepis sp.	,,
ABC	Rhynia sp.	Plantæ
BC	Hornea sp.	,,
C	Asteroxylon sp.	,,

Upper.

BC	Archanodon jukesi	Pelecypoda
ABC	Holoptychius nobilissimus	Pisces
C	Bothriolepis sp.	,,
ABC	Archæopteris hibernica	Plantæ
BC	Bothrodendron kiltorkense	,,

CARBONIFEROUS.

Lower.

C	Saccammina carteri	Protozoa
ABC	Lithostrotion basaltiforme	Anthozoa
BC	,, junceum	,,
C	Lonsdaleia floriformis	,,

Carboniferous—Lower—contd.

C	Zaphrentis enniskilleni	Anthozoa
BC	Caninia sp.	,,
BC	Dibunophyllum sp.	,,
C	Michelinia sp.	,,
BC	Cyathophyllum murchisoni	,,
C	Amplexus coralloides	,,
ABC	Syringopora sp.	,,
BC	Actinocrinus triacontadactylus	Crinoidea
C	Orbitremites ellipticus	Blastoidea
ABC	Orthis resupinata	Brachiopoda
ABC	Productus giganteus	,,
ABC	,, semireticulatus	,,
ABC	Spirifer striatus	,,
ABC	Syringothyris cuspidata	,,
ABC	Martinia glabra	,,
ABC	Terebratula hastata	,,
ABC	Pugnax acuminatus	,,
C	,, pugnus	,,
BC	Seminula ficoides	,,
C	Sanguinolites plicatus	Pelecypoda
ABC	Posidonomya becheri	,,
C	Conocardium sp.	,,
ABC	Euomphalus pentangulatus	Gastropoda
BC	Pleurotomaria carinata	,,
ABC	Glyphioceras sphæricum	Cephalopoda
C	Prolecanites compressus	,,
BC	Phillipsia sp.	Trilobita
C	Cochliodus sp.	Pisces
ABC	Psammodus rugosus	,,
BC	Lepidodendron veltheimianum	Plantæ
C	Sphenopteris affinis	,,

Upper.

ABC	Carbonicola robusta	Pelecypoda
ABC	Anthracomya phillipsi	,,
ABC	Pterinopecten papyraceus	,,
ABC	Gastrioceras listeri	Cephalopoda
BC	Spirorbis sp.	Vermes
C	Megalichthys hibberti	Pisces
ABC	Calamites sp.	Plantæ
C	Annularia sp.	,,
ABC	Lepidodendron aculeatum	,,
ABC	Sigillaria sp.	,,
ABC	Stigmaria ficoides	,,
C	Sphenophyllum sp.	,,
C	Sphenopteris obtusiloba	,,
ABC	Pecopteris arborescens	,,
C	Mariopteris muricata	,,
BC	Trigonocarpus sp.	,,
ABC	Neuropteris heterophylla	,,
ABC	Alethopteris lonchitica	,,
BC	Cordaites principalis	,,

PERMIAN.

C	Lingula credneri	Brachiopoda
ABC	Productus horridus	,,
C	Spirifer alatus	,,
ABC	Fenestella retiformis	Polyzoa
C	Pseudomonotis speluncaria	Pelecypoda
ABC	Schizodus obscurus	,,

PERMIAN—contd.

ABC	Bakewellia antiqua	Pelecypoda
[1]BC	Popanoceras	Cephalopoda
[1]BC	Medlicottia	,,
BC	Palæoniscus sp.	Pisces
BC	Walchia piniformis	Plantæ

[1] Not British.

Glossopteris flora.

ABC	Glossopteris browniana	Plantæ
BC	Gangamopteris sp.	,,
C	Schizoneura gondwanensis	,,

TRIASSIC.

English Trias (Keuper and Bunter).

ABC	Estheria minuta	Phyllopoda
C	Labyrinthodon	Amphibia
BC	Cheirotheroid footprints	
BC	Rhynchosauroid footprints	
C	Equisetites arenaceus	Plantæ
C	Voltzia heterophylla	,,

Continental Trias.

ABC	Encrinus liliiformis	Crinoidea
BC	Cœnothyris vulgaris	Brachiopoda
ABC	Gervillia socialis	Pelecypoda
BC	Myophoria simplex	,,
ABC	Ceratites nodosus	Cephalopoda
C	Arcestes sp.	,,
BC	Trachyceras sp.	,,

Rhætic.

C	Pseudomonotis fallax	Pelecypoda
ABC	Pteria contorta	,,
ABC	Chlamys valoniensis	,,
ABC	Protocardium rhæticum	,,
BC	Ceratodus latissimus	Pisces
C	Saurichthys	,,
C	Acrodus minimus	,,

JURASSIC.

Lower Lias.

ABC	Pentacrinus briareus	Crinoidea
ABC	Spiriferina walcotti	Brachiopoda
ABC	Hippopodium ponderosum	Pelecypoda
BC	Ostrea liassica	,,
BC	Pinna folium	,,
ABC	Plagiostoma gigantea	,,
ABC	Gryphæa arcuata	,,
ABC	Cardinia listeri	,,
C	Modiola scalprum	,,
C	Pholadomya ambigua	,,
BC	Pleurotomaria anglica	Gastropoda
C	Schlotheimia angulata	Cephalopoda
C	Arietites turneri	,,
ABC	Psiloceras planorbis	,,

Lower Lias—contd.

ABC	Oxynoticeras oxynotum	Cephalopoda
C	Uptonia jamesoni	,,
C	Liparoceras striatum	,,
C	Coroniceras bucklandi	,,
BC	Asteroceras obtusum	,,
C	Ægoceras capricornu	,,
C	Hybodus sp.	Pisces
ABC	Plesiosaurus sp.	Reptilia
ABC	Ichthyosaurus	,,

Middle Lias.

C	Ophioderma	Ophiuroidea
ABC	Terebratula punctata	Brachiopoda
BC	Aulocothyris resupinata	,,
ABC	Rhynchonella tetrahedra	,,
ABC	Protocardium truncatum	Pelecypoda
ABC	Oxytoma cygnipes	,,
BC	Pecten æquivalvis	,,
ABC	Amaltheus margaritatus	Cephalopoda
ABC	Paltopleuroceras spinatum	,,

Upper Lias.

BC	Lingula beani	Brachiopoda
ABC	Leda ovum	Pelecypoda
ABC	Inoceramus dubius	,,
C	Posidonomya bronni	,,
ABC	Trigonia literata	,,
C	Gresslya donaciformis	,,
ABC	Hildoceras bifrons	Cephalopoda
ABC	Dactylioceras commune	,,
BC	Grammoceras striatulum	,,
ABC	Harpoceras falciferum	,,
BC	Belemnites vulgaris	,,

Bajocian.

C	Montlivaltia trochoides	Anthozoa
BC	Clypeus sinuatus	Echinoidea
ABC	Holectypus hemisphæricus	,,
C	Nucleolites clunicularis	,,
ABC	Terebratula fimbria	Brachiopoda
C	,, phillipsi	,,
ABC	Rhynchonella cynocephala	,,
BC	Haplœcia straminea	Polyzoa
BC	Ostrea flabelloides	Pelecypoda
BC	Limatula gibbosa	,,
ABC	Trigonia costata	,,
ABC	Pholadomya fidicula	,,
BC	Astarte elegans	,,
C	Ceromya concentrica	,,
C	Pleurotomaria punctata	Gastropoda
ABC	Nerinæa cingenda	,,
BC	Parkinsonia parkinsoni	Cephalopoda
C	Ludwigella concava	,,
BC	Ludwigia murchisonæ	,,
C	Strophodus magnus	Pisces
ABC	Equisetites columnaris	Plantæ
C	Nilssonia compta	,,
BC	Tæniopteris vittata	,,
BC	Coniopteris hymenophylloides	,,
C	Ginkgo digitata	,,
ABC	Williamsonia sp.	,,

Bathonian.

BC	Isastræa limitata	Anthozoa
ABC	Apiocrinus parkinsoni	Crinoidea
BC	Nucleolites woodwardi	Echinoidea
BC	Acrosalenia wiltoni	,,
C	Ornithella ornithocephala	Brachiopoda
ABC	,, digona	,,
ABC	Terebratula maxillata	,,
C	Dictyothyris coarctata	,,
ABC	Ostrea acuminata	Pelecypoda
C	,, sowerbyi	,,
C	Trigonia impressa	,,
BC	Gervillia acuta	,,
C	Lima cardiiformis	,,
BC	Pseudomonotis braamburiensis	,,
BC	Capulus rugosus	Gastropoda
C	Purpuroidea morrisi	,,
C	Teleosaurus sp.	Reptilia

Cornbrash.

C	Terebratula intermedia	Brachiopoda
ABC	Ornithella obovata	,,
C	Microthyris lagenalis	,,
ABC	Pseudomonotis echinatus	Pelecypoda
BC	Goniomya V-scripta	,,
ABC	Macrocephalites macrocephalus	Cephalopoda

Oxfordian.

BC	Rhynchonella varians	Brachiopoda
ABC	Gryphæa dilatata	Pelecypoda
ABC	Sigaloceras calloviense	Cephalopoda
BC	Quendstedtoceras lamberti	,,
ABC	Belemnites hastatus	,,
BC	,, oweni	,,

Corallian.

ABC	Isastræa explanata	Anthozoa
ABC	Thecosmilia annularis	,,
BC	Thamnastræa arachnoides	,,
ABC	Cidaris florigemma	Echinoidea
ABC	Hemicidaris intermedia	,,
ABC	Nucleolites scutatus	,,
C	Ostrea gregaria	Pelecypoda
C	Pecten fibrosus	,,
BC	Camptonectes lens	,,
BC	Lima rigida	,,
BC	Trigonia clavellata	,,
ABC	Bourgetia striata	Gastropoda
BC	Pseudomelania heddingtonensis	,,
C	Aspidoceras perarmatum	Cephalopoda
BC	Cardioceras cordatum	,,
BC	Perisphinctes plicatilis	,,
C	Gyrodus punctatus	Pisces

Kimeridgian.

BC	Serpula variabilis	Vermes
ABC	Rhynchonella inconstans	Brachiopoda
ABC	Exogyra virgula	Pelecypoda
ABC	Ostrea deltoidea	,,
C	Thracia depressa	,,
C	Nucula menkei	,,
C	Trigonia juddiana	,,
ABC	Perisphinctes biplex	Cephalopoda
ABC	Aptychus	,,
BC	Pliosaurus sp.	Reptilia

Portland Beds.

ABC	Isastræa oblonga	Anthozoa
ABC	Trigonia gibbosa	Pelecypoda
BC	Protocardium dissimile	,,
C	Pecten lamellosus	,,
ABC	Cerithium portlandicum	Gastropoda
C	Pleurotomaria rugosa	,,
BC	Olcostephanus giganteus	Cephalopoda
C	Mesodon damoni	Pisces

Purbeck Beds.

ABC	Ostrea distorta	Pelecypoda
BC	Cyrena media	,,
ABC	Viviparus fluviorum	Gastropoda
BC	Archæoniscus brodiei	Isopoda
C	Lepidotus minor	Pisces
C	Goniopholis	Reptilia
C	Chara sp.	Plantæ
C	Bennettites nidiformis	,,

CRETACEOUS.

Wealden Beds.

ABC	Unio valdensis	Pelecypoda
ABC	Viviparus fluviorum	Gastropoda
BC	Cypris sp.	Ostracoda
ABC	Lepidotus mantelli	Pisces
C	Iguanodon sp.	Reptilia
C	Equisetites lyelli	Plantæ
BC	Bennettites gibsonianus	,,
BC	Tempskya schimperi	,,

Speeton Series.

C	Toxaste complanatus	Echinoidea
BC	Pecten cinctus	Pelecypoda
BC	Exogyra sinuata	,,
BC	Holcostephanus speetonensis	Cephalopoda
C	,, asterianus	,,
ABC	Hoplites regalis	,,
ABC	Belemnites lateralis	,,
ABC	,, jaculum	,,
BC	,, brunsvicensis	,,

Lower Greensand.

BC	Raphidonema faringdonense	Porifera
BC	Holocystis elegans	Anthozoa
BC	Hyposalenia wrighti	Echinoidea
C	Toxaster complanatus	,,
ABC	Terebratula sella	Brachiopoda
BC	Rhynchonella gibbsi	,,
ABC	Exogyra sinuata	Pelecypoda
BC	Gervillia sublanceolata	,,
C	Trigonia caudata	,,
BC	Thetironia minor	,,
C	Perna mulleti	,,
ABC	Parahoplites deshayesi	Cephalopoda
C	Meyeria vectensis	Decapoda

Selbornian.

(Gault.)

BC	Terebratula biplicata	Brachiopoda
ABC	Inoceramus sulcatus	Pelecypoda
ABC	,, concentricus	,,
ABC	Nucula pectinata	,,

Selbornian (Gault)—contd.

BC	Alaria carinata	Gastropoda
C	Hoplites auritus	Cephalopoda
BC	,, interruptus	,,
ABC	,, lautus	,,
ABC	,, splendens	,,
C	Schloenbachia rostrata	,,
BC	Douvilleiceras mammillatum	,,
BC	Hamites intermedius	,,
ABC	Belemnites minimus	,,
C	Palæocorystes stokesi	Decapoda
C	Thrissopater salmoneus	Pisces

(Upper Greensand Facies.)

ABC	Siphonia tulipa	Porifera
ABC	Chlamys asper	Pelecypoda
BC	Neithea quadricostata	,,
BC	Protocardium hillanum	,,
C	Trigonia aliformis	,,
C	Exogyra conica	,,
C	Cytherea plana	,,
ABC	Turritella granulata	Gastropoda
BC	Lamna appendiculata	Pisces

Cenomanian.

C	Stauronema carteri	Porifera
ABC	Discoidea cylindrica	Echinoidea
ABC	Holaster subglobosus	,,
C	Pecten orbicularis	Pelecypoda
C	Plicatula inflata	,,
BC	Ostrea frons	,,
ABC	Scaphites æqualis	Cephalopoda
BC	Schloenbachia varians	,,
BC	Turrilites costatus	,,
BC	Acanthoceras rotomagense	,,
BC	Actinocamax plenus	,,

Turonian.

ABC	Holaster planus	Echinoidea
BC	Micraster cor-bovis	,,
BC	Terebratula semi-globosa	Brachiopoda
C	Terebratulina lata (gracilis)	,,
ABC	Rhynchonella cuvieri	,,
ABC	Inoceramus mytiloides (=labiatus) . . .	Pelecypoda
BC	,, brongniarti	,,
C	Pachydiscus peramplus	Cephalopoda
BC	Ptychodus decurrens	Pisces
C	Macropoma sp.	,,

Senonian

ABC	Ventriculites sp.	Porifera
C	Parasmilia centralis	Anthozoa
C	Caryophyllia cylindracea	,,
ABC	Marsupites testudinarius	Crinoidea
C	Uintacrinus sp.	,,
C	Phymosoma kœnigi	Echinoidea
ABC	Conulus albogalerus	,,
ABC	Echinocorys scutatus	,,
C	Micraster cor-testudinarium	,,
ABC	Micraster cor-anguinum	,,

Senonian—contd.

BC	Terebratula carnea	Brachiopoda
BC	Rhynchonella plicatilis	,,
ABC	Spondylus spinosus	Pelecypoda
C	Ostrea lunata	,,
BC	Actinocamax quadratus	Cephalopoda
ABC	Belemnitella mucronata	,,
C	Ptychodus rugosus	Pisces

EOCENE.

Thanet Sands.

C	Astarte tenera	Pelecypoda
BC	Corbula regulbiensis	,,
ABC	Cyprina morrisi	,,
BC	Aporrhais sowerbyi	Gastropoda

Woolwich and Reading Beds.

BC	Ostrea bellovacina	Pelecypoda
ABC	Cyrena cuneiformis	,,
C	,, tellinella	,,
ABC	Melania inquinata	Gastropoda
BC	Potamides funatus	,,

London Clay.

BC	Vermicularia bognoriensis	Vermes
BC	Pholadomya margaritacea	Pelecypoda
ABC	Pinna affinis	,,
BC	Pectunculus brevirostris	,,
ABC	Teredo sp.	,,
C	Pyrula smithi	Gastropoda
ABC	Voluta nodosa	,,
C	Natica hantonensis	,,
ABC	Nautilus regalis	Cephalopoda
BC	Xanthopsis leachi	Decapoda
C	Hoploparia gammaroides	,,
BC	Lamna obliqua	Pisces
ABC	Myliobatis toliapicus	,,
BC	Nipadites sp.	Plantæ

Bracklesham Beds.

ABC	Nummulites lævigatus	Protozoa
BC	Litharæa websteri	Anthozoa
BC	Crassatella compressa	Pelecypoda
ABC	Cardita planicosta	,,
BC	Conus deperditus	Gastropoda
BC	Pleurotoma attenuata	,,
C	Voluta selseiensis	,,
ABC	Turritella sulcifera	,,
C	Belosepia sepioidea	Cephalopoda
C	Galeocerdo latidens	Pisces
C	Palæophis sp.	Reptilia

Barton Beds.

BC	Nummulites planulatus	Protozoa
ABC	Crassatella sulcata	Pelecypoda
BC	Cardita sulcata	,,
C	Corbula ficus	,,
ABC	Chama squamosa	,,
BC	Dentalium striatum	Scaphopoda

Barton Beds—contd.

C	Strombus bartonensis	Gastropoda
BC	Rostellaria ampla	,,
BC	Rimella rimosa	,,
ABC	Murex asper	,,
BC	Typhis pungens	,,
C	Triton argutus	,,
BC	Fusus porrectus	,,
ABC	Clavella longæva	,,
C	Sycum bulbiforme	,,
C	Oliva branderi	,,
BC	Conorbis dormitor	,,
ABC	Pleurotoma rostrata	,,
ABC	Voluta luctatrix	,,
BC	,, athleta	,,
ABC	Turritella imbricataria	,,
BC	Xenophora agglutinans	,,

OLIGOCENE.

Mull Beds.

C	Ginkgo biloba	Plantæ
C	Platanus hebridicus	,,
C	Corylus macquarrii	,,

Headon Series.

ABC	Cytherea incrassata	Pelecypoda
C	Cyrena obovata	,,
C	Psammobia compressa	,,
BC	Pisania labiata	Gastropoda
ABC	Ancillaria buccinoides	,,
ABC	Cerithium concavum	,,
BC	Potamides ventricosus	,,
BC	Neritina concava	,,
ABC	Viviparus lentus	,,
ABC	Limnæa longiscata	,,
ABC	Planorbis euomphalus	,,
ABC	Melania muricata	,,
C	Amia sp.	Pisces
C	Lepidosteus sp.	,,
BC	Chara lyelli	Plantæ

Osborne and Bembridge Beds.

BC	Cyrena pulchra	Pelecypoda
BC	Melania excavata	Gastropoda
C	,, acuta	,,
BC	Helix occlusa	,,
BC	Amphidromus ellipticus	,,
ABC	Planorbis discus	,,
ABC	Potomaclis turritissima	,,

Hamstead Beds.

ABC	Corbula subpisum	Pelecypoda
ABC	Cyrena semistriata	,,
C	Voluta rathieri	Gastropoda
BC	Potamides plicatus	,,
BC	Rissoa chastelli	,,

MIOCENE.

(Continental.)

C	Clypeaster altus	Echinoidea
C	Scutella subrotunda	,,
C	Congeria conglobata	Pelecypoda
C	Ostrea crassissima	,,
C	Ranella marginata	Gastropoda
C	Pyrula rusticula	,,

PLIOCENE.

Diestian.

ABC	Arca diluvii	Pelecypoda

Coralline Crag.

ABC	Fascicularia aurantium	Polyzoa
C	Alveolaria semiovata	,,
ABC	Terebratula grandis	Brachiopoda
ABC	Pecten opercularis	Pelecypoda
C	Chlamys gerardi	,,
BC	Lucina borealis	,,
BC	Cyprina islandica	,,
ABC	Astarte omalii	,,
BC	,, mutabilis	,,
ABC	Cardita senilis	,,
BC	Venus casina	,,
BC	Trophon alveolatum	Gastropoda
ABC	Turritella incrassata	,,
ABC	Scaphella lamberti	,,

Red Crag.

BC	Balanophyllia calyculus	Anthozoa
C	Echinus woodwardi	Echinoidea
ABC	Mactra ovalis	Pelecypoda
BC	,, arcuata	,,
BC	Mytilus edulis	,,
ABC	Pectunculus glycimeris	,,
ABC	Cardium parkinsoni	,,
C	Artemis exoleta	,,
ABC	Chrysodomus contrarius	Gastropoda
BC	,, antiquus	,,
C	Trophon costiferum	,,
ABC	Buccinopsis dalei	,,
ABC	Nassa reticosa	,,
BC	Purpura tetragona	,,
ABC	,, lapillus	,,
BC	Natica millepunctata	,,
ABC	Turritella incrassata	,,
C	Trivia avellana	,,
BC	Carcharodon megaladon	Pisces

Norwich Crag.

ABC	Nucula cobboldiæ	Pelecypoda
ABC	Cardium edule	,,
ABC	Astarte borealis	,,
C	Mactra subtruncata	,,
BC	Tellina obliqua	,,
BC	Cerithium tricinctum	Gastropoda
ABC	Littorina littorea	,,
BC	Natica clausa	,,

PLEISTOCENE.

ABC	Tellina balthica	Pelecypoda
BC	Pecten islandicus	,,
ABC	Cyrena fluminalis	,,
BC	Astarte compressa	,,
C	Unio littoralis	,,
BC	Bythinia tentaculata	Gastropoda
C	Rhinoceros tichorhinus	Mammalia
C	Hippopotamus amphibius	,,
ABC	Elephas primigenius	,,
ABC	Hyæna crocuta	,,
BC	Salix polaris	Plantæ
C	Betula nana	,,

Zoological Bibliography and Publication.—*Report of Committee* (Prof. E. B. POULTON, *Chairman*; Dr. F. A. BATHER, *Secretary*; Mr. E. HERON-ALLEN, Dr. W. EVANS HOYLE, Dr. P. CHALMERS MITCHELL, Mr. W. L. SCLATER).

THE Committee deeply regrets the resignation, for reasons of health, of its highly valued member, Dr. W. E. Hoyle.

During the past year the Secretary has been kept busy with correspondence on subjects dealt with in previous reports, and in replying to requests for copies of those reports. The advice of the Committee has been sought, and sometimes taken, by various editors.

Among journals with which there has been such communication may be mentioned *The British Journal of Experimental Morphology*, *The Journal of Helminthology*, *Proceedings of the Geologists' Association*, *Transactions of the Leeds Geological Association*, *Geological Magazine*, and *Annals and Magazine of Natural History*; also the publications of the Royal Society of Medicine, of the Tropical Diseases Bureau, of the Raffles Museum, Singapore, of the Colombo Museum, and the Royal Society of West Australia.

A letter on the meaning of 'publication' appeared in *The Times Literary Supplement* for November 5, 1923. There was some correspondence in *Nature* of November 3 and December 1 and 15, 1923, on the sizes of publications, arising out of a resolution by the Conference of Delegates. The last Report of the Committee has been reprinted in *Revue Critique de Paléozoologie* (XXVIII., pp. 50-52, June 1924).

The question of *sizes of periodical publications*, referred to in the preceding paragraph, has also been raised in other quarters, notably by Mr. J. F. Pownall, who has submitted, to this Committee among other bodies, a number of proposals for the coordination of publication. A brief report on Mr. Pownall's proposals was, by request of the President of the Association, furnished by the Secretary of the Committee. Mr. Pownall's proposals may be summarised as follows :—

1. That all scientific publications should be in a standard format.
2. That all papers should commence on a fresh recto page.
3. That all papers should have an index catch-word or words at their head.
4. That memoranda, cuttings, etc., should be written or fixed on pages of the same standard size.
5. That librarians, research workers, and others would thus be enabled to form libraries on their subjects.

All these proposals are good, and many attempts to carry out Nos. 1, 2, 3 have been made during the past forty years by editors familiar with the needs of the scientific worker.

As regards format, the Committee ventures to differ somewhat both from Mr. Pownall's suggestion No. 1 and from the resolution passed by the last Conference of Delegates. That resolution endorsed the recommendation of a previous Committee of this Association (*Report* for 1895, p. 77), namely, that the size should be demy octavo (approximately $9 \times 5\frac{3}{4}$ in. or $22{\cdot}5 \times 14{\cdot}5$ cm.). This was then undoubtedly the usual size, and presumably had been found the most convenient. If it has been adopted by any Society, a change should not be made without careful consideration.

It was, however, about the same time that the new methods of process-reproduction rendered it possible to illustrate scientific papers more freely than had been the case, and a larger size of page was soon found necessary for the half-tone blocks that became

popular. The Report of the British Association Committee was almost immediately followed by an enlargement of the *Proceedings* of the Royal Society to royal octavo. Since then, the number of journals that have adopted that size, or one closely approaching it, has greatly increased, and one rarely sees a new periodical of importance selecting any smaller format. Your Committee considers that it would be hopeless, even were it advisable, to struggle against this current. The recommendation it desires to make is therefore that these two main sizes—demy octavo as above, and royal octavo (approximately $10\frac{1}{4} \times 7$ in.) — should be recognised as appropriate to scientific publications (excluding those in quarto or in folio), and that every endeavour should be made to conform to one or other of those formats, and to eschew fancy sizes. Probably most local societies and old-established journals will be well advised to continue with their demy octavo as recommended by the Conference of Delegates. But journals established for the newer branches of science should, as the great majority of them do, adhere to royal octavo.

Other subjects of animated discussion by correspondence have been the irritating repagination of reprints, the confused or cumbrous method of making references, and the omission to indicate the subject of one's paper in its title, except by a Latin name that is often incorrect and, if correct, is familiar only to the specialist. But on these matters your Committee contents itself for the present with referring to its previous reports.

Your Committee has learned with pleasure of the progress being made in the compilation of a World List of Scientific Periodicals, with an indication of the principal libraries in Great Britain and Ireland where they are filed. Professor A. W. Pollard, Keeper of Printed Books, British Museum, the honorary editor, has completed a card list of over 20,000 scientific periodicals in existence now or since 1900; the first 128 pages of an editorial edition have been printed, and are in circulation to the centres which have undertaken to mark the lists with the names of libraries. The complete work, which may be subscribed for at 2*l.* 2*s.*, may be expected early in 1925. This scheme, initiated by the Conjoint Board of Scientific Societies, has been transferred to 'The World List,' an incorporated Society with registered offices at the Zoological Society, Regent's Park, London, N.W. 8. The Council of Management consists of Dr. Chalmers Mitchell, chairman, Sir Arthur Schuster, and Mr. Robert Mond, with Miss Joan B. Procter as Secretary. The Carnegie United Kingdom Trust has given a guarantee towards the cost.

Your Committee recommends its reappointment, with the addition of Dr. W. T. Calman, and with a grant of 1*l.* to meet incidental expenses, and requests that this report be published.

'Zoological Record.'—*Report of Committee* (Sir S. F. HARMER, *Chairman*; Dr. W. T. CALMAN, *Secretary*; Prof. A. DENDY, Prof. E. S. GOODRICH, Prof. D. M. S. WATSON) *appointed to co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the 'Zoological Record.'*

YOUR Committee has appointed Professor D. M. S. Watson, F.R.S., to be its representative on the Zoological Record Association, which has been established with the object of organising additional support for the 'Zoological Record.'

The grant of 50*l.* was paid over to the Zoological Society in January last, as a contribution towards the cost of preparing and publishing Volume LIX. of the Record (for 1922).

It should be pointed out that the donations towards the cost of the Record are being received on the understanding that, if the net loss to the Zoological Society on the volume should be less than 500*l.*, the balance will be carried forward to the following volume. As Volume LIX. is not yet published at the time of writing this report, it is not known whether there will be any balance or not. If there is, it is unlikely to be of any size, and it cannot yet be assumed that the need for assistance will be any less urgent in the case of Volume LX. which is now in course of preparation. On these grounds your Committee hope very much that the Council of the British Association will agree to renew the grant of 50*l.* for another year.

In future years it is hoped that, with increasing sales, the loss on the annual volumes of the Record may diminish to an amount which the Zoological Society may be willing to meet unaided. With this end in view, your Committee would especially appeal to the members of the Sectional Committee of Section D to help in increasing the circulation of the Record. The sale of the separate parts, especially, could, it is believed, be

greatly increased if the help which they are able to give to individual workers were more widely known.

Your Committee has reason to believe that the Record Committee of the Zoological Society will welcome suggestions as to ways in which the Record might be improved, in the arrangement or selection of its materials or otherwise, so as to render it more useful to the working zoologist, and your Committee would be glad to receive and collate such suggestions from members of Section D and to forward them to the Zoological Society.

Your Committee asks to be reappointed, with a renewal of the grant of 50*l*.

Parthenogenesis.—*Report of Committee* (Prof. A. Meek, *Chairman*; Mr. A. D. Peacock, *Secretary*; Dr. J. W. Heslop Harrison *and* Mr. R. Bagnall).

Further work on the parthenogenesis of saw-flies is reported as follows:

The species Thrinax mixta Kl. *and T. maculata* Kl.—New work on the egg-laying, pupation, morphology and parthenogenesis of these species has been published in a paper, 'The Biology of *Thrinax mixta* Kl. and *T. maculata* Kl.,' in the 'Proceedings of the University of Durham Philosophical Society,' Vol. 6, Pt. 5, 1923.

Sex Ratios.—The sex ratios of the European parthenogenetic species, about 130, are being investigated, but, as the records concerning each species are scanty and scattered, progress necessarily is slow. The wide experience of the Rev. F. D. Morice, M.A., and Miss E. F. Chawner has been placed at the disposal of the secretary, and has proved of great value. It is hoped to publish results within the next year.

Continuous thelytokous parthenogenetic reproduction in Allantus (*Emphytus*) *pallipes* Spin *and Pristiphora pallipes* Lep.—This is the fourth consecutive season for parthenogenetic strains of these species. Strains of the former have reproduced for eight successive generations, and of the latter for ten without resort to sexual methods. No weakening of the strains is perceptible. The former has never yet yielded a male among the 1,100 specimens reared.

Sexuality of Pristiphora pallipes.—A paper 'On the Males and an Intersex-Like Specimen of the Parthenogenetic Saw-fly *Pristiphora pallipes* Lep.' has been published in the 'British Journal of Experimental Biology,' Vol. 1, April 1924. In it, the morphology of the rare males and an intersex-like specimen are discussed from specimens (2♂♂ and 1 ♂) obtained under special experimental conditions where the eggs, during maturation, were immersed in a solution of magnesium sulphate (0·2 per cent.).

Repeat experiments to ascertain the possible *rôle* of this chemical as a sex-changing agent, so far, have yielded negative results, but a number of experiments are still not concluded.

A third male was obtained on April 15, 1924, from a batch of eggs subjected, during maturation, to immersion in water of temperature 38·2° C. > 17·5° C. Repeat experiments are in progress.

The sexual behaviour of the females and the rare males has been studied. The females are a-dechandrous, *i.e.* refuse the males, but proceed to lay. One pairing, however, was effected, and from the nineteen offspring reared to pupæ, seventeen imagines have emerged, all females. (See summary under Section D of this year's programme.) Publication will take place in the 'Brit. Journ. Exp. Biol.'

Sex-change experiments.—Attempts to influence the sex of the female-producing *Allantus* (*Emphytus*) *pallipes* by subjecting eggs during maturation to physical and chemical agents have yielded negative results. Agents used include uranium oxide, X-rays, ultra-violet light, electric fields, manganese chloride and magnesium sulphate.

Pteronidea (*Nematus*) *ribesii* Scop.—Experiments on the parthenogenetic conditions existing in this species continue, and it is hoped soon to correlate these with cytological observations from new material, and from that of the late Professor L. Doncaster, whose preparations, through the kindness of Professor J. Stanley Gardiner, have been placed at the disposal of the secretary.

Gametogenesis.—A large amount of material from several species has been read, and papers are in preparation. In this connection, the discovery may be announced here of 1, nurse cells in the male gonad, and 2, large accessory nuclei which cluster around the nucleus of the egg growing in the ovariole of *Platycampus luridiventris* Fall.; these resemble those found by Buchner in many other hymenoptera, but not observed by him in many species of saw-flies which he examined.

Pathology.—A myxosporidian (?) parasite has been discovered in the gonads of *Thrinax* sp. and is being studied.

On Certain of the More Complex Stress Distributions in Engineering Materials.

—*Report of Committee* (Prof. E. G. COKER, *Chairman*; Profs. L. N. G. FILON *and* A. ROBERTSON, *Secretaries*; Profs. A. BARR, GILBERT COOK, *and* W. E. DALBY, Sir J. A. EWING, Prof. A. R. FULTON, Dr. A. A. GRIFFITHS, Prof. J. J. GUEST, Dr. B. P. HAIGH, Profs. Sir J. B. HENDERSON, C. E. INGLIS, F. C. LEA, A. E. H. LOVE, *and* W. MASON, Sir J. E. PETAVEL, Dr. F. ROGERS, Dr. W. A. SCOBLE, Mr. R. V. SOUTHWELL, Dr. T. E. STANTON, Mr. C. E. STROMEYER, Mr. G. I. TAYLOR, *and* Mr. J. S. WILSON).

Introduction.

THE Committee submit as their Report the following contributions, which include an account of an investigation on the fatigue strength of a hard drawn steel, both with and without the stress concentrations arising from a circular hole, and several papers dealing with the scientific side of testing.

I. Photo-Elastic Methods of Testing. Prof. E. G. Coker, F.R.S.

II. A Standard Form of Test-Piece. Prof. W. E. Dalby, F.R.S.

III. The Impressed Conditions of Fatigue Tests. A. A. Griffiths, D.Eng.

IV. The Influence of Circular Holes on the Fatigue Strength of Hard Steel Plates. Prof. B. P. Haigh, D.Sc., and Mr. Albert Beale.

V. The Distribution of Stress in Fatigue Test-Specimens (Torsion and Bending). Prof. W. Mason, D.Sc.

VI. The Effects of Inaccuracy of Axial Loading. Prof. Andrew Robertson, D.Sc.

VII. The Drop of Stress at the Yield Point of Ductile Materials. Prof. Andrew Robertson, D.Sc.

VIII. Note on Impact Experiments. Mr. R. V. Southwell, M.A.

I. Photo-Elastic Methods of Testing.

By Prof. E. G. COKER, F.R.S.

The apparent simplicity of ordinary mechanical tests of the strength of materials, as usually made by tension, compression, shearing, and like forces, is so far from being true, that photo-elastic experiments on transparent models of test bars form a useful qualitative guide to their real behaviour under load, and moreover provide, in many cases, means of measuring the stress distributions which actually occur, the study of which latter may eventually lead to a real simplification and fuller understanding of this branch of experimental enquiry.

Although bending tests of materials come first historically, they have not quite the primary importance which simple tension tests have now assumed, when an estimate of the properties of an engineering material is required, and, since most of the interesting features in this latter kind of test lie in effects produced at the ends, whether enlarged or not for gripping purposes, it will be convenient to commence by considering the case of a very wide plate subjected to uniform stress at its ends, and to examine what effects are produced when semicircular notches are formed in the sides, with their centres at the ends of a transverse section. Members of this type with notches close together have occasionally been used for testing the strength of materials, although they give little information about its tensile properties, but, as is evident, this primary form is capable of development into forms now in use as standard types of test bars.

An approximate investigation by Leon[1] shows that the maximum stress at the central point of the circular contour is $2\,p$ where p is the stress applied in a very wide plate, but the boundary conditions are not fully satisfied. It is, perhaps, easier to form a rough idea of the stress distribution obtained by considering a very wide tension member under a stress of intensity p with a central hole of radius a, for which there is an exact solution. Taking one half of the member when divided by a central longitudinal plane, upon which latter stress systems are imposed corresponding to those which the other half of the member produced before the division took place, we have at the circular contour a varying stress of $3\,p$ at A, fig. 1, falling to zero stress at B when $\theta=30°$, and becoming a compression of value $-p$ at C, while along the free side C D we have to annul a normal stress

$$\widehat{\theta\theta}=\tfrac{1}{2}\,p\left\{1+\frac{a^2}{r^2}-\left(1+3\frac{a^4}{r^4}\right)\right\}$$

having a value $-p$ at C, zero at $r=a\sqrt{3}$ and afterwards rising to a small tensional value before it ultimately disappears. There is also a radial stress $\widehat{rr}$ along this edge, which is zero at C, and increases slowly to its full value of p in a manner so much resembling that actually found in a notched tension member of this kind that it may be considered to represent this latter approximately. The main effect is, therefore, to estimate the effect of annulling $\widehat{\theta\theta}$ along the vertical edge. We shall then have zero stress at C, and presumably a somewhat smaller change along the contour A C as the distance from C increases, so that we may expect to find a stress at A somewhat greater than $2\,p$, which experiments show to be correct.

For example, in the case of the notched transparent member shown in the lower part of fig. 1, where the stress distribution is experimentally determined, we find a maximum stress of 1,340 lbs. per sq. in. across the minimum section, due to a mean applied stress $p_m=734$ lbs. per sq. in., from which latter it is necessary to find the equivalent value of the stress p applied to an infinite plate from an approximate relation

$$p_m a(c-1)=\int_a^{ca}\widehat{\theta\theta}.dr$$

where

$$\widehat{\theta\theta}=\frac{a^4}{r^4}+\frac{a^2}{r^2}+2$$

and $c\,a=$ the half-width of the plate and the expression for $\widehat{\theta\theta}$ has been assumed from Leon's approximate investigation.

This last equation gives $p=620$ lbs. per sq. in. approximately, so that the increase of intensity at the notch is 2·16 in this instance.

The great variation of stress intensity across the minimum section, accompanied as it is by cross stress having here a maximum value of about $\frac{1}{3}\,p$, renders this form of specimen unsuitable for tension tests, since, if the material is approximately elastic up to fracture, the stress system is never simple tension, and, if it becomes semi-plastic or wholly plastic, it is still possible that there may be two principal stresses of the same sign at all points of the minimum cross-section except the ends, and, should the material fail in shear, the apparent strength obtained will then be greater than that of a simple tension member, as is often found to be the case.

Standard test-bars for plates, as found in specifications for testing materials, can be derived from this form, by introducing a parallel length of the same width as the minimum cross-section between the notches, and the stress system produced when observed in circularly polarised white light is shown in fig. 2 for a transparent tension member, in which the stress in the central part is arranged to give an intensity represented by a very sensitive purple-red field so that the somewhat higher stress near the form of the straight and curved sides, and represented by a blue field, is very apparent.

As may be inferred, and is in fact proved by experiment, this marked increase of stress, at a point just beyond the central straight portion of the contour, may be multiplied almost indefinitely by increasing the curvature of the joining curves. Thus, for example, in a transparent model of a flat tension member with ends enlarged to 0·932 in. width from 0·460 in. at the centre, and a connecting curve of $\frac{1}{4}$ in. radius, the stress increased from 1,200 lbs. per sq. in. to 1,480 lbs. per sq. in., or 23·4 per

[1] *Österreichische Wochenschrift für den Öffentlichen Baudienst*, February 1908.

Fig. 2.—Natural Colour Photograph of the Stress Distribution at the enlarged end of a tension test bar.

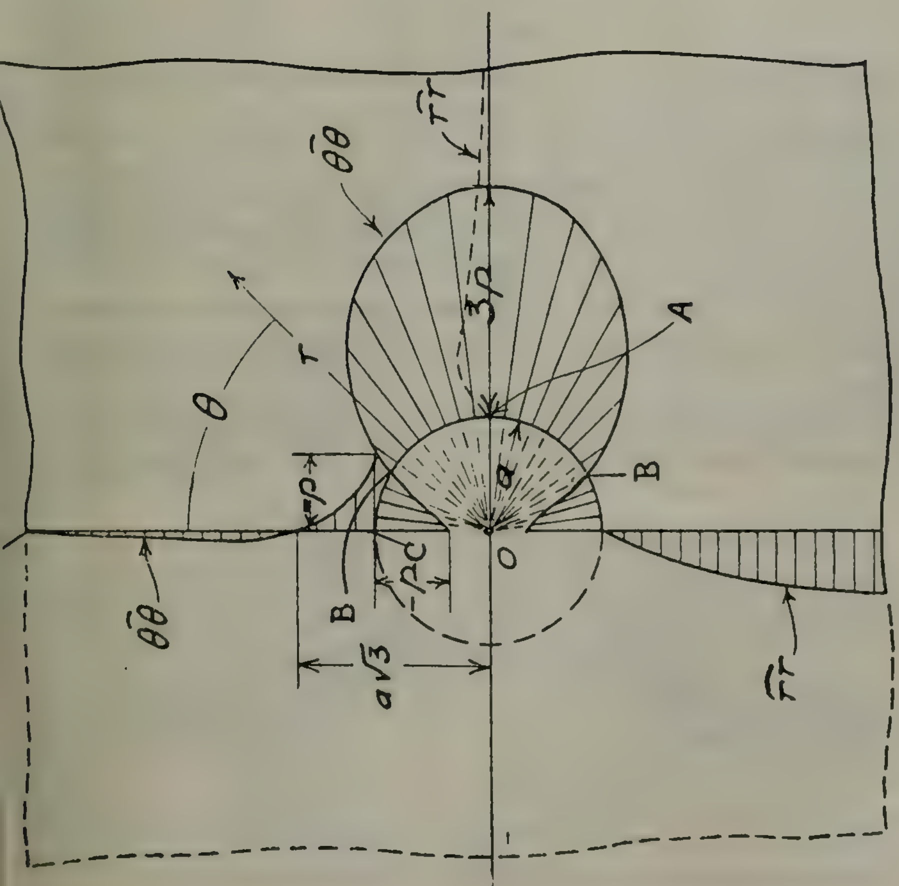


Fig. 1a.
Stress distribution at a hole in an infinitely wide tension member.

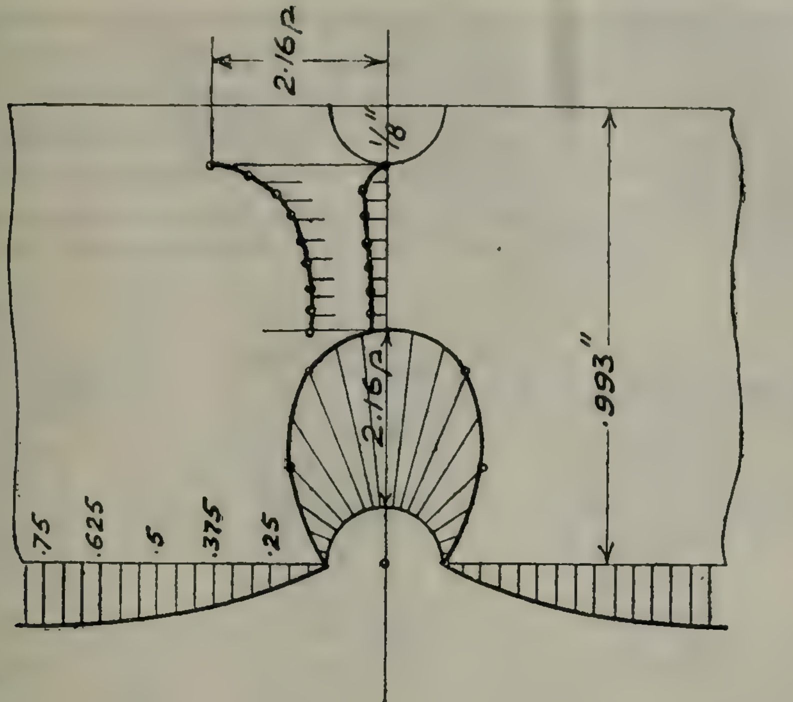
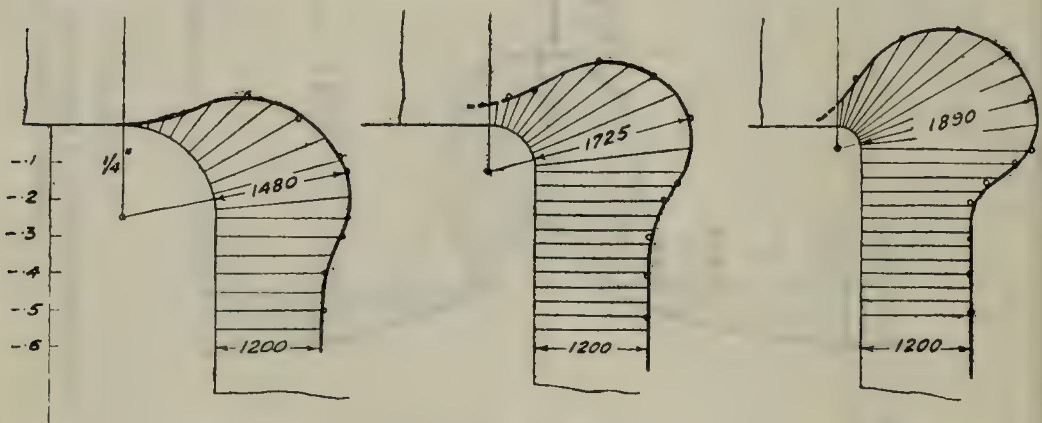


Fig. 1b.
Stress distribution at a semicircular notch in a tension member of limited width.

cent., with a distribution curve as represented in fig. 3 (*a*), where it will be noted that the maximum value is reached, not at the join of the straight with the curved part, but at a point where the tangent to the contour makes an angle of about 15° with the axis of the specimen. With a radius of $\frac{1}{8}$ in. the distribution (*b*) gives nearly 44 per cent. increase, while a further decrease to $\frac{1}{16}$ in. radius gives (*c*), nearly 58 per cent. increase, and when the experiment was pushed to the extreme limit by making the curve as small as possible, a very small load was found to produce permanent stress at the re-entrant angle.

These photo-elastic effects afford an explanation why materials like cast iron, hard brass, and even thin india-rubber specimens often break at sections which start from



(*a*) (*b*) (*c*)

FIG. 3.

Stress distribution along the contours of test-bars near the enlarged ends.

these points of maximum stress intensity, indicated in this reproduction of a natural colour photograph of a tension test-bar.

The stress picture also raises another interesting matter, as it shows that the field of complex stress, represented by a variation in the colour field, invades the central parallel portion of the test-bar, so that not all of this can be in pure tension, and it is at once seen to be necessary to so fix the gauge limits, inside which stress and strain are measured, that no complex stress is possible.

An examination (1) of numerous models of test-bars given in standard specifications shows that very few specifications are free from criticism on this latter point, and especially is this so when the gauge length is short and the specimens are of circular cross-section.

Taking the question of gauge length first, without the additional complication of a circular cross-section, we have, in a short member, a distribution of stress shown by the semi-perspective sketch, fig. 4, in which the greater of the two principal stresses

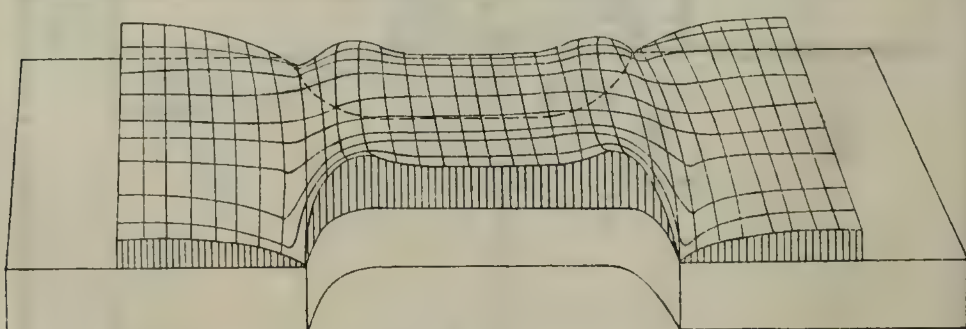


FIG. 4.

The stress distribution in a flat tension test-bar with enlarged ends.

at any point is shown as an ordinate to a flat face of the test-bar. Experiment shows that, in general, this surface, if the test-bar is sufficiently short, is concave in the central portion, and only tends to become plane over the central portion if the length between the shoulders is sufficiently great, while for the enlarged ends it is convex, tending to flatness at a sufficiently great distance away from the central part, with two rather complicated saddle-shaped surfaces over the changes of section connecting the various portions. It therefore comes about that, if the specimen is sufficiently short, no part of the member is ever stressed in pure tension within the elastic limit by forces applied at the ends. It is also comparatively easy, with a transparent model, to determine what length, if any, is in pure tension by plotting the zero isoclinics in plane polarised light, which latter curves at once effect the separation of the parts in pure tension from those under complex stress. Although not strictly necessary, such results have been compared with complete surveys of stress intensity in a plate tension member, and these are found to unite in giving the same delimitations of areas of the plate under pure stress as is determined by the isoclinics, while, to demonstrate its practical importance, the length of the parallel part of the tension member has also been determined in a few cases for which no pure tension is possible.

Thus, in the case of the flat specimen just described, it is found that there is no purely tensional stress in the central straight part if this is less than 0·32 in. in length, when the connecting curves are $\frac{1}{4}$ in. radius, but this length is increased slightly with smaller arcs, and reaches its maximum value of 0·42 in. when the re-entrant angle is as sharply defined as it is possible to make it.

Specimens of Circular Cross-section.

The general effect produced by changing the flat member to one of circular cross-section of the same contour is probably to intensify all the variations of stress described above, for change of the cross-section becomes proportional to the square of the transverse dimensions, instead of to the first power, and it is therefore most likely that the local concentration of stress near the ends of the central parallel part is larger than before, while the complex stress has been shown experimentally to penetrate further into the central parallel part than in the corresponding plane case. This can be observed by surrounding a specimen of cylindrical shape and enlarged ends with a flat-sided jacket of corresponding but slightly larger bore in every part, so that the small space between can be filled with a liquid of the same refractive index as the specimen and its jacket. A plain cylindrical rod under tension shows a system of colour bands parallel to its axis, due to uniform stress in the varying thickness under view; but if the specimen has enlarged ends, these bands begin to curve towards the axis before reaching the enlargements, owing to complex stress, and it is therefore possible to obtain the length under pure tension, which is always found to be less than the corresponding plane case.

In one case, for example, of a short cylindrical specimen of 2 in. gauge length taken from a Standard Specification, the central part has a diameter of 0·564 in. to give a convenient cross-sectional area with a parallel portion $2\frac{1}{4}$ in. long connected to enlarged ends $\frac{7}{8}$ in. in diameter by curved profiles of $\frac{7}{8}$ in. radius. A model in the flat shows that this gauge length is just sufficient, while a truly cylindrical shape shows that complex stress invades the gauge length for a distance of $\frac{1}{8}$ of an inch at each end, so that a parallel length of $2\frac{1}{2}$ in. is required for a 2 in. gauge length.

The Effects of Indentations in Tension Members.

The reduction of ultimate strength in a tension test-bar, due to the effects of a centre punch mark or letter stamped upon it, is often evident from the failure of the piece at a section where this local injury occurs, but its influence naturally extends beyond its immediate neighbourhood.

Even a comparatively small local pinch, such as that exerted by the screw points of an extensometer, may be serious, as the lines of principal stress are then distorted, although not nearly so much in practice as in the case shown by fig. 5A, where the transverse pinch is one-third of the longitudinal load, and therefore indicates complex stress over a considerable field. In general, however, stress across the line of the pinch rises to a very considerable magnitude at the surface, as indicated by the experimental values shown in fig. 5B, which are found to be in fair agreement with the theoretical expressions obtained by Professor Filon.[2]

[2] Appendix 5.

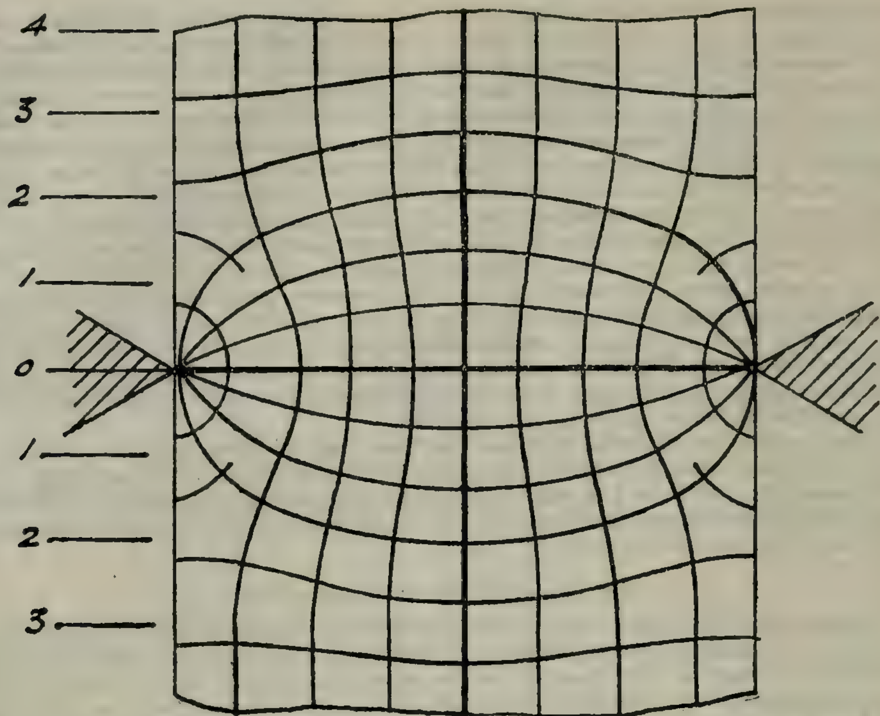
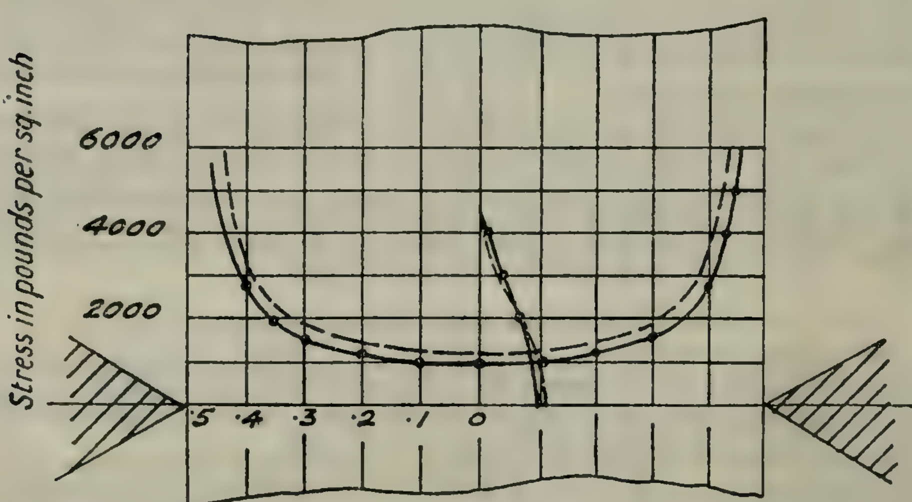


FIG. 5A.

Lines of principal stress in a tension member due to a lateral pinch of intensity equal to one-third of the longitudinal pull.



• Measured stresses

- - - - -Calculated stresses

FIG. 5B.

Comparison of the experimental and theoretical values of the stress distribution across the section and along the central line of the test-bar.

In order to avoid this source of error, Professor Dalby has designed a new form of test-bar, described in a section of this Report, in which the specimen is turned from a solid bar with collars spaced at a convenient distance apart, and the extension between these latter is measured by a suitable mechanism bearing lightly against the inner faces of the projections. Although a plane model of this test-bar does not give the stress distribution accurately, it shows some interesting features which are probably present in the cylindrical form in a somewhat more pronounced fashion. A very small extent of collar is stressed in a symmetrical manner, and in the neighbourhood of this section there is a small field of complex stress symmetrical with respect to the collar, and rising to a maximum value near the join of the straight contours with the curved fillets, and resuming a mean stress value at a short distance away. This rise of stress is what one would expect from the results obtained with the enlarged ends of specimens described earlier, but it is found here that, provided the fillet does not undercut the collar, a variation in curvature makes very little difference to the stress distribution, and therefore is quite different in this respect from the case of an enlarged end of an ordinary test-piece. This result seems connected with the fact that, here, the change in the curvature of the lines of principal stress is practically determined by the thickness of the collar, and although they expand into this latter, their curvature and the stress concentration produced are not influenced much by the curvature of the contour at the junction of the collar with the test-piece.

Compression Tests.

It is well known that the end surfaces of blocks of material for compression tests require to be faced with great care, and for some materials, like concrete, a coating of plaster-of-Paris over the surfaces in contact with the pressure plates of the testing

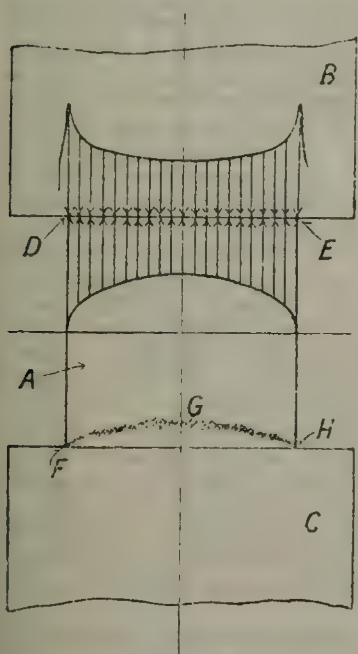


FIG. 6A.
Stress distribution at the ends of blocks of unequal sizes when pressed together.

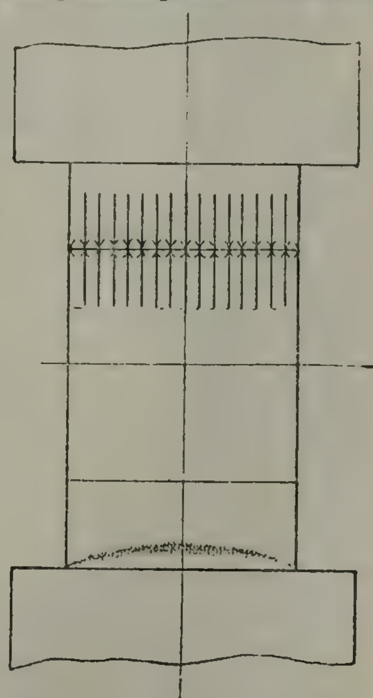


FIG. 6B.
Modified arrangement to secure pure compression stress in the central block.

machine is found to improve the consistency of the results of such tests. It is possibly not realised, however, that, in general, when two flat surfaces are pressed together, the pressure between them may vary a great deal, even though they be of the same material. If, for example, a block A (fig. 6A) is subjected to compression between two larger plates B and C, there is always a considerable rise of stress at the points D and E, and measurements show [3] that in the upper block the curve of distribution, very close

[3] Appendix 4.

to the edge, has two pronounced peaks as indicated, while in A there is a somewhat similar distribution, which occurs in a more or less degree within the zone marked by the dotted curve F G H. When the materials pressed together are not alike, the effect is still more pronounced, and it cannot be got rid of when the faces are initially plane and are of different areas. It is, however, possible to obtain perfectly uniform compression stress well away from the end plates, and this suggests a means of obtaining perfect compression stress in a rectangular block by the interposition of short compression members of the same cross-section (fig. 6B) as the block under test, so that all the inequalities of stress distribution are kept within these, and do not penetrate into the test portion. Photo-elastic experiments show that this does actually give an extremely close approximation to pure compression stress when all the contact areas of the blocks are scraped surfaces and exactly parallel, and although the modified test is more difficult to make, no simpler way of getting rid of these complex end effects has proved of value. In general, it is also seen to be inaccurate to determine elastic properties of the compression block A (fig. 6A) by strain measurements between the faces of the blocks B and C.

The Testing of Cement.

Although cement, whether used alone or as part of an aggregate, is employed as a material to resist compression stresses, its mechanical properties are often determined by tension tests alone, but happily American and Canadian procedure recognises compression tests as an important element of this branch of testing.

As regards tension tests of cement, it may be truly said that the shapes of all standard forms are such as to produce throughout the briquette a highly complex stress system, as may easily be seen when a transparent model of any form is loaded and viewed in a circularly polarised field of light.

This is, perhaps, even more noticeable in that part of the briquette between the grips than at the waist, for here the relatively great contact stresses imposed by the grips produce compression stresses of much greater intensity than the tension system in the waist, and since the minor principal stresses are also small, the photo-elastic effect is great, whereas at the waist of the briquette the tensional stress system across the minimum cross-section is accompanied by cross stress also tensional throughout and of considerable magnitude, so that the differential photo-elastic effect is relatively much smaller, although the stresses when separated are found to be great. In an early attempt [4] to determine the stress system in transparent models of briquettes, advantage was taken of the fact that the maximum stress at the waist is at the contour, where there is no cross stress, and it was then found that in the British Standard this maximum stress was 1·75 times the mean average stress across the section, while in the American and Canadian forms this ratio was 1·70. Lately the former standard has been investigated more elaborately and the stress system has been measured for the whole of the briquette. It is therefore possible to indicate the chief results for the waist, which is the important part, as, although the stress system across the grips occasionally causes failure due to compression stress, it is a comparatively rare occurrence, owing to the great ability of cement to resist that type of stress. On a transparent briquette of full size, the measurements of $(p \pm q)$ at the waist, with a load giving a mean average stress of 500 lbs. per sq. in., are plotted on the accompanying fig. 7, from which it will be seen that the normal tension p varies from 1·74 to 0·8 times the mean average stress, confirming the earlier value for the maximum stress here within one per cent., but the q curve of minor principal stress is comparatively large and for the greater part of the section is only slightly less than 50 per cent. of the mean stress applied.

Such a system of stresses acting on a specimen of material obviously requires very careful interpretation if it is to be useful in giving information regarding its tensional properties, and it may be added that lateral measurements on cement briquettes, when a month or so old, indicate that the stress system produced in them under load is much the same. Unfortunately, standard briquettes, like standard test-bars, differ from country to country, and there is much need of co-ordination, so that a test of a material in one country can be directly compared with another without the necessity of applying a correction factor, even if this latter is feasible, to take into account the peculiarities of form of one standard as compared with another.

Standard cement briquettes, as they exist to-day, seem particularly difficult to bring into some degree of unity in this respect; but as cement, like steel, is a material

[4] Appendix 8.

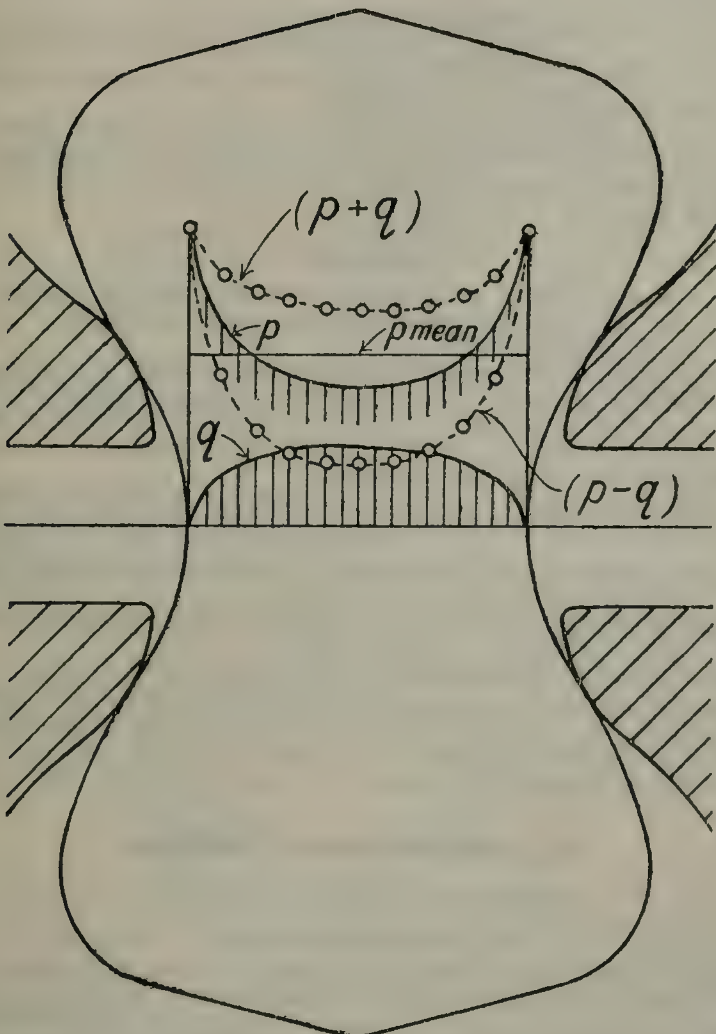


FIG. 7.
Stress distribution at the waist of a British Standard Cement Briquette.

of universal use, it would not only be of scientific value to do so, but also be of commercial use. Possibly one of the simplest ways to effect this without interfering too much with existing testing machinery would be to remodel each briquette by the addition of a short parallel part to the waist of sufficient length to enable the central part to develop a purely tensional stress in it.

Photo-elastic experiments show that the minimum length required in the case of the British Standard is 0·88 in., and cement briquettes of this shape, when tested, indicate by the uniformity of lateral contraction across the central part that pure tension stress exists at this cross-section, so that the mean average stress and the true stress are one and the same.

Further exploration might possibly suggest other and better ways of solving this difficulty of the want of uniformity in standard methods of testing cement and other materials, which can only come about by the research and co-operation of the representative bodies now existing in most countries.

In this brief survey of one branch of an extensive field of research, it has not been possible to give detailed accounts of the experimental and theoretical data utilised, and for this and other information the reader may be referred to the following papers, some of which have been quoted above.

APPENDIX.

(1) 'The Determination by Photo-Elastic Methods of the Distribution of Stress in Plates of Variable Section, with Some Applications to Ships' Plating.' E. G. Coker, *Trans. Inst. Naval Architects*, 1911.

(2) 'Photo-Elastic Measurements of the Stress Distribution in Tension Members used in the Testing of Materials.' E. G. Coker, *Min. Inst. Civil Engineers*, 1918-19.

(3) 'Tension Tests of Materials.' E. G. Coker, *Engineering*, January 1921.

(4) 'Contact Pressures and Stresses.' Prof. E. G. Coker, K. C. Chakko, and M. S. Ahmed, *Proc. Inst. Mech. Engineers*, 1921.

(5) 'On the Approximate Solution for the Bending of a Beam of Rectangular Cross-Section under any System of Load.' Prof. L. N. G. Filon, *Trans. R.S.*, Series A, vol. 201.

(6) 'The Effects of Scratches in Materials.' E. G. Coker, *Proc. of the Engineering Conference of the Institution of Civil Engineers*, 1921.

(7) 'Stress Concentration due to Notches and like Discontinuities.' Prof. E. G. Coker and Dr. Paul Heymans, *B.A. Report*, 1921.

(8) 'The Distribution of Stress at the Minimum Section of a Cement Briquette.' E. G. Coker, *International Association for Testing Materials, New York Congress*, 1913.

(9) 'Des Recherches Récentes sur la Photo-Elasticimétrie ayant rapport à son application dans les Problèmes Posés en Construction.' E. G. Coker, *La Société des Ingénieurs Civils de France*, 1922. See also *Engineering*, June 16, 1922.

II. A Standard Form of Test-Piece.

By Professor W. E. Dalby, *F.R.S.*

1. *The Flanged Test-Piece.*

During my researches on the elastic properties of metals, I found that the best form of test-piece to use was one in which the gauge length is defined by flanges, as shown in fig. 8. When the gauge length is defined by centre dots on the test-piece, clips have to be used, each carrying a pair of pointed screws, which are driven into the centre dots, and the points of the screws deepen the dots, or, better, make their own centre dots. The pointed screws must be spring-loaded in order that they may maintain their grip on the test-piece as its diameter contracts under test.

I have tried many forms of these clips, and have found some fairly satisfactory, but no form of spring-loaded pointed clip is so satisfactory as flanges turned on the test-pieces themselves.

The practical disadvantage of clips for elastic tests is that the points cannot be satisfactorily driven into hard steel, and in soft metal, like copper, the pits made by the points elongate as the test-piece stretches. The single advantage of using clips is that the extension is measured on the central portion of a bar of uniform diameter. But when the extension is small, as in elastic testing, the flanges have a negligible influence on the result, and therefore the elastic modulus determined from a gauge

length defined on one specimen with dots and on a second specimen with flanges is the same within experimental error.

When stretching is carried to the point at which the elastic limit is passed and the metal begins to flow, the influence of the flanges begins to be felt. The total effect of flanges is to reduce the total extension of the gauge length about 3 per cent. in soft materials. This may appear a disadvantage, but it is no disadvantage if test-pieces are made of similar form. Then, whatever the form chosen, the end effects are included in all the tests in the same way and the results are strictly comparative.

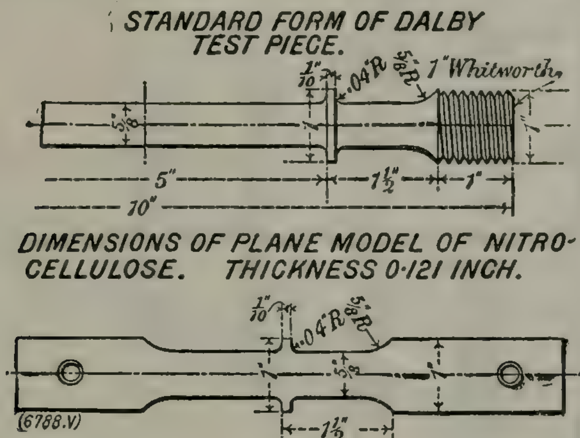


FIG. 8.

Having decided to adopt as a standard the test-piece shown in fig. 8, I carried out two experimental researches to investigate :—

(*a*) The effect of the flanges on the value of E and on the final extension of the gauge length, and

(*b*) The validity of the law of similarity when applied to test-pieces of this kind.

2. *Comparative Experiments.*

(*a*) The test-pieces were cut from the same bar of mild steel of which the chemical analysis is :—

Carbon . . .	0·15 per cent.
Silicon . . .	0·057 ,,
Sulphur . . .	0·064 ,,
Phosphorus . .	0·052 ,,
Manganese . . .	0·99 ,,

Two test-pieces were prepared, one with flanges and one plain, and both were turned accurately to ⅝ in. diameter along the gauge length, like fig. 1. A Ewing extensometer was used to find the modulus of elasticity of the plain bar, and an automatic record was taken with the Dalby Elastic Recorder from the flanged bar. The modulus of elasticity was calculated from the record.

The results are :—

With the Ewing Extensometer on a plain bar ⅝ in. diameter, 5 in. gauge length . . . . E=13300

With the Dalby Elastic Recorder on a flanged bar ⅝ in. diameter, 5 in. gauge length . . . . . . E=13320

These figures are within experimental error.

Repeated experiments led to the conclusion that the elastic extensions and the small quasi-elastic extensions leading to the plastic extensions are not materially affected by the flanges.

The test-pieces were afterwards broken, so as to investigate the effect on the final extension. It was found that the final extension of the flanged bar was about 3 per cent. less than the final extension of the plain bar.

The conclusion may therefore be stated as follows :—

1. Flanges have no material effect on the elastic extension of the length between

them, so that E can be determined from a test-piece of this form from the load-extension diagram with an accuracy sufficient for all practical purposes.

2. The influence of the flanges is to slightly reduce the ultimate extension in comparison with the extension of a plain bar of equal gauge length. In the soft steel used extension may be taken at 3 per cent. less, allowing a plus or minus error of 1 per cent. for variation of the quality of the material.

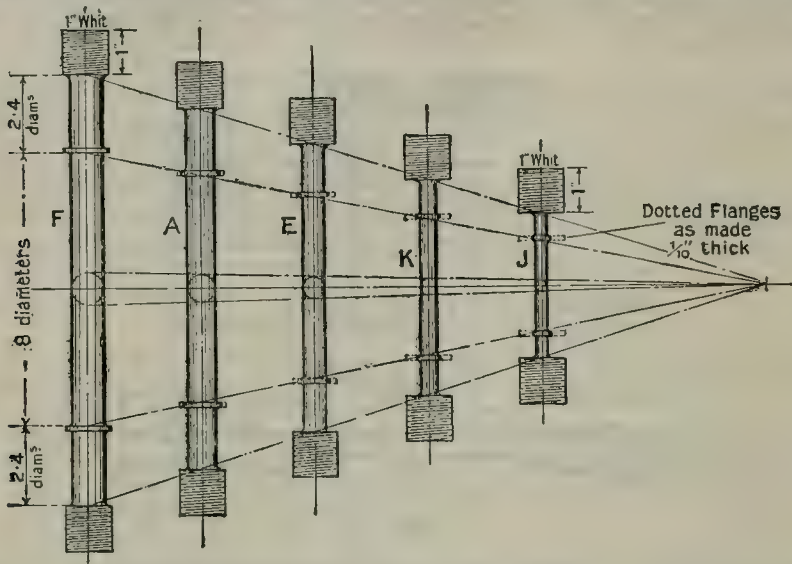


FIG. 9.

(*b*) The next step was to investigate the validity of the law of similarity when applied to a flanged test-piece.

Test-pieces were prepared in which the gauge length was eight times the diameter. The longest gauge length was 6 in. and the shortest was 2 in., the corresponding diameters being $\frac{3}{4}$ in. and $\frac{1}{4}$ in. Strict similarity was departed from only in the diameter and thickness of the flanges, which were 1 in. diameter and $\frac{1}{10}$ in. thick in each specimen. The test-pieces were cut from the same bar and all were annealed at 900° C. before turning.

Having regard to the slight difference in quality of the bar from outwards to its core, and remembering that the quality of the core is practically concentrated in the

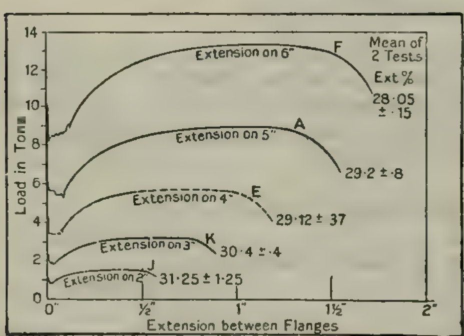


FIG. 10.

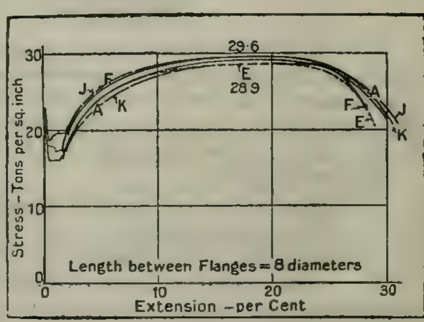


FIG. 11.

smaller test-pieces, the results of the experiments show that each bar gave the same percentage elongation within the limits of experimental error.

Further details of this test will be found in my book on the 'Strength and Structure of Materials,' from which fig. 9, which shows a series of bars, fig. 10, a series of load-extension diagrams, and fig. 11, a set of corresponding stress-extension diagrams, are taken.

3. *Prof. Coker's Experiments to Determine Distribution of Stress in Region of Flanges.*

Having established experimentally that flanges do not affect the determination of E, I asked Professor Coker whether he would examine the distribution of stress in the region of the flanges of a test-piece under load. A xylonite test-piece was prepared to the dimensions of fig. 8, and Professor Coker kindly tested it in his apparatus. His results disclosed that there was no stress in the flanges except at the root, where there was a slight concentration of stress, which was, however, perfectly symmetrical, in consequence of which, as the bar extends elastically, the flanges move down without distortion, so that the distance between the flanges is an accurate measure of the elastic extension of the gauge length which they define. Professor Coker continued his researches to find the distribution produced by points. This, however, Professor Coker would probably like to discuss himself.

III. The Impressed Conditions of Fatigue Tests.

By A. A. Griffiths, *D.Eng.*

In practice, the results of fatigue tests are almost invariably given in terms of ranges or limits of stress. For example, statements such as 'the superior and inferior limits of stress were maintained at $+15$ and -5 tons per sq. in. respectively' are usual. Now, as a matter of fact, very few fatigue-testing machines are so arranged as to render it possible to maintain any fixed limits of stress in the test-piece. The only machines in common use which are designed for this purpose are machines of the Haigh type, imposing direct pull and push, of controlled magnitudes, on a uniformly stressed test-piece. In practically all other cases the stress can only be controlled indirectly by controlling the external loads (*e.g.* bending and twisting moments) applied to non-uniformly stressed test-pieces, or by imposing constraints on the deformation of the test-pieces.

In all such cases, the expression of the results in terms of stresses depends on an application of the mathematical theory of elasticity, and consequently involves the assumption that both limits of stress lie within the range of proportionality. Modern researches have shown that this assumption is inadmissible in the case of the majority of common metals. It is usually found not only that one or both of the fatigue limits lie outside the limits of proportionality, but also that the extent of the deviation from proportionality is a function of the number of repetitions and of the previous history of the piece.

It follows that the results obtained with the several types of machine now in use are not directly comparable; the stated stress limits are, in general, purely nominal, inasmuch as they do not represent stresses actually existing in the material.

It is therefore necessary to classify machines according to the nature of the conditions imposed by the machine, with any given setting, on the parts of the test-piece in which fracture occurs, and to avoid making direct comparisons between results obtained with machines belonging to different classes. It should be remarked, moreover, that the characteristics of the testing machine only determine the general nature of the 'impressed conditions,' as they may conveniently be called—their precise specification would require, in addition, a complete knowledge of the stress-strain relations of the material.

The following broad classification of impressed conditions is suggested as a basis for such a classification of testing machines :—

I. Specific strain. In this case the limits of strain are maintained constant by the machine, independently of any variations in the stress, due to the process of fatigue.

II. Stress diminishing as strain increases. In this case the conditions are intermediate between I. (above) and III. (below).

III. Specific stress. In this case the limits of stress are maintained constant independently of any variations in the strains, due to the process of fatigue.

IV. Stress increasing as strain increases.

Some well-known types of fatigue-testing machines may now be considered in the light of the foregoing discussion.

In the Wöhler rotating-beam machine, the bending moment at the place of ultimate fracture is kept constant. If a solid test-piece is used, a comparatively small part of the section is undergoing overstrain at any instant of time, so that the strain in that part is determined by the elastic deformation of the remainder under a constant

couple. It follows that the impressed conditions must approximate closely to Class I, the approximation being closer the less the deviation from proportionality within the fatigue limits. In the case of thin hollow test-pieces, the approximation will not be so close, owing to the greater proportion of overstrained to elastically strained material.

In the Haigh electro-magnetic machine, as mentioned above, the impressed conditions fall in Class III.

In the Stromeyer alternating torsion machine, the test-piece is fixed to a flywheel at one end, and the system is caused to execute forced vibrations by means of a small alternating rotation impressed on the other end. The torque range is varied by varying the running speed, which is below the speed of resonance. In this machine any increase in the amplitude of twist in the test-piece must be accompanied by an increase in the amplitude of the flywheel, and, therefore, by an increase in the torque. If thin hollow test-pieces are used, they must be under practically uniform stress at any instant of time, whence it follows that any increase of strain must involve an increase of stress, so that the impressed conditions fall in Class IV.

If, however, solid test-pieces are used, the conditions are quite different, and are determined principally by the torque twist curve of the piece and the proportion of overstrained to elastically strained material. If only an infinitesimal skin is suffering overstrain, the conditions clearly fall in Class I. (unless the machine is running at the critical speed). At the other extreme the conditions may, perhaps, reach Class III. In most cases, however, it will probably be safe to assume that the Stromeyer machine using solid test-pieces yields impressed conditions falling within Class II.

In practice, the precise specification of impressed conditions is of considerable importance. In some tests recently made by Gough at the National Physical Laboratory, on soft iron and low and medium carbon steels, it was found that the nominal limiting fatigue stresses were lower in the Haigh machine than in the Wöhler (in the latter, there was practically no difference between the results obtained with solid and hollow test-pieces), while in the Stromeyer machine, solid and hollow test-pieces always gave different results. In the latter case, the hollow test-pieces gave nominal fatigue limits from 12 per cent. to 16 per cent. lower than the solid ones ; in conformity with the theory, the difference was greater for the more ductile materials.

As an instance of the importance of impressed conditions, as revealed by the above figures, suppose that it is desired to discriminate experimentally between Guest's law of specific shear stress and Haigh's law of specific strain energy, as applied to fatigue limits. According to the former law, the ratio of the fatigue range in pure shear to the fatigue range under tension-compression should be 0·5 ; according to Haigh's law it should be about 0·62. Now, the difference between these two figures is not much greater than the variations of nominal fatigue limiting stresses already obtained by Gough ; it is clear, therefore, that no tests capable of discriminating between the two laws can be made unless precautions are taken to secure, in both cases, impressed conditions substantially equivalent to specific stress.

IV. The Influence of Circular Holes on the Fatigue Strength of Hard Steel Plates.

By Professor B. P. Haigh, *D.Sc.*, *M.Inst.C.E.*, *and* Mr. Albert Beale, *Whitworth Senior Scholar.*

A small hole drilled in a plate subject to pulsating stresses, weakens it in a degree which depends on the nature of the metal and on the mode of pulsation of the stresses. Thus, a comparatively small hole drilled through the flange of a high-tensile steel chassis-frame may reduce the fatigue strength by one-half or more, on account of the concentration of stress round the hole ; while, on the other hand, rivet holes in a mild steel tension member of a bridge may have little effect, beyond reducing the strength in the same proportion as the cross-sectional area.

This paper has as objects : (1) To describe experiments, illustrating the dangerous effects of holes drilled in hard-drawn steel plates, and (2) to develop a working rule which will allow for the effect of redistribution of stress due to primary hysteresis.

The concentrations of stress induced by discontinuities of circular or elliptic profile, in uniform plates stressed in one direction by pull or push, have been investigated mathematically by Suyehiro,[1] Inglis,[2] and others. On the hypothesis that the metal behaves elastically and isotropically, the intensities of the complex stresses acting at

different points near the opening have been evaluated in terms of the uniform applied stress acting across a remote section perpendicular to the direction of loading. In the case of a circular hole, the maximum intensity of stress occurs on the margin of the opening, on a diameter perpendicular to the direction of the applied load, and is three times as great as the uniform stress at a point remote from the hole. If the metal behaved elastically, therefore, a plate stressed in this manner might be expected to suffer fatigue, and crack when the applied stress was only one-third of that required to crack a similar plate without the hole.

The concentrations of stress induced by discontinuities of any form, in uniform plates, have been investigated also by the methods of optical analogy developed by Filon,[3] Coker,[4] and others; and in cases which admit of mathematical analysis, the results obtained by optical means agree with those calculated mathematically. It is inferred that the materials used in the optical experiments are sufficiently elastic for the purpose, and that the optical method may be used with confidence when the mathematical analysis proves intractable. The mathematical and optical methods are regarded, therefore, as approximately equivalent, and may be adopted alternatively, according to the circumstances of the case. Both, however, are based on the hypothesis that the metal behaves elastically within the range of stress under consideration.

Since actual metals seldom behave elastically within the ranges of stress that promote fatigue, it is to be expected that the conclusions derived from mathematical analysis may require to be modified, in different ways for different metals, when the object is to deduce the increased liability to fatigue caused by a discontinuity. In a British Association Paper (1922) and a contribution to the Report of this Committee,[5] it was shown that in the case of mild steel plates subjected to pulsating stresses—such as vary without changing their direction—the load required to cause fatigue was nearly as great as that required to cause yield in steady tension. This degree of immunity was attributed to the beneficial effect of the slight plastic strain, resulting in a redistribution of the concentrated stresses.

Further experiments have since been carried out with a harder steel; and, in order to facilitate the comparison between elastic theory and direct experiment, the flat strips used as test-pieces have been pierced with only a single small circular hole on the centre-line.

Experimental Data.

The metal used in the tests was a cold-rolled strip of high-tensile steel, kindly supplied by Mr. J. D. Brunton, of Musselburgh, and was received in a coil that could be unwound and straightened without hammering. Surface blemishes were only slight, and were removed with fine emery before the pieces were tested. The section of the strip measured 1·50 in. by 0·064 in. In a preliminary tensile test, the elongation obtained on fracture measured only 1·4 per cent., although the local reduction of area at fracture was 42 per cent. The yield-point and ultimate tensile strength were nearly coincident at 36·3 tons/in.^{2}. The extensions under successive loads, being plotted, were found to give a curved graph that shows no definite limit of proportionality. A strip that was loaded repeatedly gave a graph sufficiently straight to indicate an approximate value of Young's Modulus, namely $E=12{,}400$ tons/in.^{2}. The metal is regarded as typical of high-tensile cold-rolled strip of good quality.

The fatigue tests were carried out in a Haigh electro-magnetic testing machine fitted with clamps similar to those described in the communication to the Report for 1922; but the clamps were fitted with special copper washers that effectively minimised the difficulty initially experienced from fracture at the grips. The frequency of loading was in all cases 2,000 cycles per minute.

The applied stress acted as a pulsating tension, being compounded of a steady tension S, and a smaller alternating load A. Thus the tension varied from a maximum $(S + A)$ to a minimum $(S - A)$.

In the first series of tests, the immediate object was to find the limiting value of the alternating component A, which, in combination with a fixed steady component S arbitrarily chosen as 18 tons/in.^{2}, produced a fatigue fracture in an *unpierced* strip. The test-pieces used were 6 in. in length, and gradually reduced in width from $1\frac{1}{2}$ in. at the ends to $\frac{1}{2}$ in. along the mid-part. The value of A was changed for successive strips; but was maintained constant for the testing of each individual strip, except in some cases (marked * below) when a second test was made on a strip which remained unbroken after an earlier one. The endurances recorded are given in the following

table, from which it is deduced that fatigue occurs when the alternating stress A exceeds 14 tons/in.^{2}, in combination with the steady stress of 18 tons/in.^{2}, corresponding to a maximum stress of 32, and a minimum of 4 tons/in.^{2}.

Table I.—Fatigue Tests on Unpierced Plates.

S = 18 Tons/In.^{2}

Specimen Number	A Tons/In.^{2}	Endurance, Millions of Cycles.
1	12	2·000 Unbroken
1*	14	1·208 Cracked
2	14	0·722 Cracked
3	13	0·872 Cracked
4	13	0·526 Cracked
5	13	8·572 Unbroken
5*	15	0·872 Cracked
6	14	0·964 Cracked
7	13·5	7·778 Unbroken
7*	15	0·910 Cracked
8	14	16·826 Unbroken
8*	14·5	1·826 Cracked
9	14	3·040 Cracked
10	15	9·818 Cracked

Failure occurred in each instance by the development of a fatigue crack from some point on the parallel middle portion. In most cases the cracks started from the edge; but in others the cracks started in the middle and ran outwards.

In the second series of tests, the strips were in all instances pierced with a single circular hole, drilled on the centre-line and at mid-length. In the first few tests, the width of the strip was reduced at mid-length as in the first series, from $1\frac{1}{2}$ in. to 1 in. or to $\frac{1}{2}$ in.; but, when it was found that satisfactory fractures could be obtained without this reduction, subsequent tests were made on strips of the full width, $1\frac{1}{2}$ in. The reduction in fatigue strength was so great that the difficulty experienced in gripping the ends in a satisfactory manner was less than in the case of the tapered but unpierced strips.

The loads applied in different tests were such that, in all cases but one, the alternating component load bore a fixed ratio, namely 14 : 18, to the steady tensile load. This being the ratio obtained in the limiting condition for the unpierced plate, it follows that if the material was perfectly elastic, this same ratio would hold between the alternating and steady components of stress throughout, and that at the point where failure starts, the actual stresses would be S = 18 tons/in.^{2}, A = 14 tons/in.^{2}. If s, a, were the components of applied stress—at a point remote from the hole—which proved to be the limiting value causing fracture, then $18/s$ ($= 14/a$) would be the value of the maximum ratio of stress-concentration due to the hole, and if the elastic theory held this would be equal to 3. Thus the maintenance of the applied stresses in this ratio enables the results to be checked at once against the theoretical values.

In recording the results in the following table, the applied stresses have been quoted indirectly through the numerical factor N, such that

$$a = \text{Applied Alternating Stress} = 14/\text{N tons/in.}^2.$$

$$s = \text{Applied Steady Tensile Stress} = 18/\text{N tons/in.}^2.$$

Thus N affords a direct indication of the reduction applied in consideration of the presence of the hole.

FIG. 12.

[To face page 329.

TABLE II.—FATIGUE TESTS ON PIERCED PLATES.

Specimen Number	Width of Plate, Ins.	Diameter of Hole, Ins.	N	Endurance, Millions of Cycles.
1	0·50	0·0365	1·0	0·008 Cracked
2	1·00	0·100	2·0	0·658 Cracked
3	1·50	0·066	2·0	0·576 Cracked
4	1·50	0·100	2·0	0·733 Unbroken (*g*)
5	1·50	0·075	3·0	5·446 Unbroken (*g*)
6	1·50	0·100	2·1	0·592 Cracked
7	1·50	0·100	2·1	2·566 Unbroken (*g*)
8	1·50	0·066	2·1	1·642 Unbroken (*g*)
9	1·50	0·100	2·15	1·126 Cracked
10	1·50	0·200	2·15	0·772 Cracked
11	1·50	0·100	2·2	8·462 Unbroken (*g*)
12	1·50	0·0365	2·1	5·660 Unbroken
12	1·50	0·0365	2·1 (*s*) 2·0 (*a*)	2·864 Unbroken
12	1·50	0·0365	2·0	0·986 Cracked

The statement 'Unbroken (*g*)' signifies that the test-piece did not crack on the pierced section, but did so at the grips. The statement 'Cracked' signifies failure in a manner appropriate to the investigation, as shown in the photographed specimens—fig. 12. The cracks originated at the margin of the hole and spread across the transverse diametral section. When the crack had extended a certain distance, which varied with the value of N, the residual metal failed in a characteristic ductile manner, plainly shown by the reflected light from the polished surfaces.

The photograph shows four pieces from Series II. and one from Series I.; and in each case the development of the fracture in the two distinct stages: (1) by the formation of a true fatigue crack, and (2) by subsequent ductile yielding of the remaining metal, is clearly shown.

It is considered that the photograph shows that any ductile yielding that may have occurred in stage (1) must have been very slight, and such as did not appreciably change the profile of the hole from a circle to an ellipse. Any yielding in this stage is probably of the nature which, in a contribution [6] to the Report of this Committee for 1923, is termed 'primary hysteresis.' While the process of fatigue is attributed to 'secondary hysteresis,' the action of 'primary hysteresis' is regarded as wholly beneficial, being the mechanism by which the stresses are redistributed in a more uniform manner than the presence of the hole would initially entail in an elastic substance. In metals that show no such primary hysteresis, it is probable that no such beneficial redistribution would occur.

Two conclusions may be drawn at once from the results tabulated, namely :—

(1) The limiting stresses for failure vary only slightly with the ratio between the diameter of the hole and the width of the plate, within the range investigated.

(2) The presence of the circular hole weakens the hard-drawn strip, subjected to pulsating tensile stress, in a manner indicated by the value $N = 2{\cdot}15$, instead of by the value $N = 3{\cdot}00$, as would be anticipated from the mathematical results based on the assumption of perfect elasticity.

Observing that the weakening effect of the hole, in the hard-drawn strip, is intermediate between the theoretical effect deduced for a perfectly elastic metal and the experimental one recorded, for a ductile mild steel, in the communication for 1923,[5] it is inferred that the action of the hole is indeed modified by the redistribution of the concentrated stresses, in the manner briefly indicated in 1922. In these circumstances, it appears desirable further to develop the argument, and to advance a convenient basis for applying the results of mathematical or optical investigations which, in their direct application, appear to over-estimate the dangerous effect of a discontinuity in a ductile metal subjected to pulsating stress.

Analysis.

Although further experiments are in progress, the foregoing data—for a particular steel, stressed with steady and alternating loads bearing a particular ratio—may profitably be analysed, as a preliminary step, in order to note the application of a simple hypothesis regarding the beneficial action of the redistribution of stress attributed to 'primary hysteresis' in the metal.

According to this hypothesis, the metal on the margin of the hole, and on the transverse diameter, becomes subject to a modified stress that ranges from $(S + 3a)$ to $(S - 3a)$, the upper limit being that which most directly governs the development of slip-bands producing primary hysteresis. The value of S is less than $3s$, the intensity that would be developed in an ideally elastic metal, and is probably very small in a metal endowed with sufficient capacity for developing primary hysteresis.

In such circumstances, fatigue occurs only when the semi-range $3a$ exceeds $A_s = A_0 (1 - (S/U)^2)$, which is then very nearly equal to A_0, the fatigue limit under a simple alternating stress, varying between equal intensities of pull and push. Thus, the nominal range of stress required to promote fatigue is

$$a = A_0/3, \text{ nearly.}$$

If $3s/U$ is high, this value may be considerably greater than $A/3 = A_0/3\ (1 - (3s/U)^2)$ —which would be the value if there was no redistribution—although equal to it when s is zero.

Since the two series of tests afford two alternative means of deducing the value of A_0, the validity of the hypothesis may be checked although, with such thin plates, the value of A_0 cannot be determined by direct experiment.

Applying the relation indicated above, the results of the second series of tests give

$$A_0 = 3a = 3 \times 14 \text{ tons/in.}^2 \div 2{\cdot}15 = 19{\cdot}5 \textit{ tons/in.}^2$$

Turning to the first series of tests, on unpierced strips, the value of A_0 may be deduced by applying Gerber's parabolic rule, namely, $A = A_0 (1 - (S/U)^2)$. Thus:

$$A_0 = 14 \div (1 - (18/36{\cdot}3)^2) = 18{\cdot}5 \textit{ tons/in.}^2$$

It may be noted that this latter value is 51 per cent. of the ultimate tensile strength, $U = 36{\cdot}3$ tons/in.^{2}; which percentage appears not unreasonable, although a somewhat lower value, from 45 per cent. to 50 per cent., is more common in such steels tested in stout bars. It appears, therefore, that the approximate agreement between the two values (within 6 per cent.) is sufficiently close to justify the use of the simple working rule, namely :—

Limit of nominal alternating component stress (a) *must not exceed* $A_0/3$.

It may be remarked, further, that the 6 per cent. discrepancy—noted above—is in the direction which may be attributed to either or both of two known effects: (1) the metal may have been hardened slightly by the ductile strain associated with redistribution; (2) the application of the Gerber parabolic rule, in relation to the first series of tests, may tend to underestimate the value of A_0 in a hard-drawn metal. In this particular case, however, the latter effect is improbable, since it is not likely that A_0 will exceed 51 per cent. of U.

In a more ductile metal, such as that investigated in the contribution to the Report for 1923, the effect of the hole is less dangerous than is indicated by mathematical analysis, even when the conclusions are modified by the rule explained above. The discrepancy may be attributed to the local hardening effect due to the slight plastic strain, associated with considerable primary hysteresis.

For example, an experimental mild steel plate, having a single circular hole on the centre-line, showed a fatigue limit approximately at the combination $s = 6{\cdot}0$, $a = 5{\cdot}5$ tons/in.^{2}, although the ultimate tensile strength was only 22 tons/in.^{2}. Applying the redistribution rule indicated, we might deduce

$$A_0 = 3a/U = 16{\cdot}5/22 = 75 \text{ per cent.};$$

but since this ratio is certainly too high, even for such a mild steel, it is inferred that local hardening must have occurred in an important degree, raising the fatigue limit by perhaps 25 per cent.

Further experiments are being directed to compare the actions of metals that may be expected to show greater and less degrees of local hardening, and in metals that do or do not exhibit primary hysteresis; and to investigate the actions of stress combinations in which the ratio $s : a$ differs in a wide range.

In the meantime, the foregoing results are published to indicate how the dangerous effects of the stress-concentrations, though definitely less than those suggested by mathematical theory applied in the most direct manner, appear to be closely related to the results of mathematical analysis.

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[1] Suyehiro, *Proc. Inst. N.A.*
[2] Inglis, *Proc. Inst. N.A.*
[3] Filon and Coker, Report of B.A. Stress Committee, 1914, pp. 201-210.
[4] Coker, Chakko and Satake, *Inst. Eng. & Shipbdrs. in Scotland*, vol. lxiii.
[5] Wilson and Haigh, Report of B.A. Stress Committee, 1923.
[6] B. P. Haigh, Report of B.A. Stress Committee, 1923.

V. Note on the Distribution of Stress in Fatigue Test-Specimens (Torsion and Bending).

By Professor W. Mason, *D.Sc.*

Experimental work published in the Reports of the Committee has shown [1] that steel may endure cycles of alternating stress, reaching to 70 millions, with accompanying hysteresis of a magnitude incompatible with elasticity. Further work has demonstrated that the hysteresis of protracted alternating tests, at ranges certainly below the fatigue range but above the limit of proportionality (under increasing alternating loading), is many times greater than hysteresis which can be classed as 'elastic hysteresis.' It must be admitted, therefore, that the portion of the Bauschinger theory which explains prolonged endurance, under equal plus and minus stresses, by the hypothesis of recovery or alteration of elastic limits, will not fit these new facts. The following fact appears to be established: prolonged repetitions of a fatigue-limit range of stress induce, in mild and medium steel, a range of strain that remains extra-elastic, not merely with reference to any primitive condition, but inasmuch as it entails persistent 'cyclical permanent set.' There is a hysteresis loop of comparatively large ratio of width to length which may persist, in the writer's experience, over 100 million cycles. This cycle appears to be exactly reversible mechanically; although, of course, it is not reversible thermodynamically.

It is usual to calculate the stresses due to ranges of torque or bending by formulæ which are built upon the assumption of perfect elasticity. Error is of course entailed by use of these formulæ, and the question arises as to the amount of this error. An interesting point that immediately presents itself is how far the stress and strain in a solid specimen are affected by the central core of elastic material; whether this core exerts a constraining influence on the extent of the cyclic extra-elastic strain; or whether, on the other hand, elastic breakdown is propagated into the core, producing therein a low value of the limit of proportionality; and arising from this is the question, which so far as the writer knows is unanswered, whether there is a 'scale' effect, *i.e.* whether the stress and strain distribution would be different for specimens of different diameters. An assumption of linear distribution of strain from axis to skin appears, however, to be justifiable on general grounds; [2] and on this basis the distribution of stress may be inferred from a comparison of alternating torsion tests on hollow and solid specimens.

Calculations have been made by the writer for the following cases:—

Alternating Torque.—The limits of the error entailed by the use of the usual formula can be calculated with a considerable degree of precision, since the real stresses in hollow specimens with thin walls can be calculated within very narrow limits. The error entailed in solid specimens of mild or medium steel is between 10 and 13 per cent. for fatigue limits of stress.

Alternating Bending (in one plane fixed relatively to the specimen of circular section).—The limits of the error have been calculated [3] and are wider than for alternating torque. The parts of the specimen affected by cyclic extra-elastic strain are two small segments only of the circular area, which makes the calculation of the error

difficult, and the figures found for the error, viz. between 10 and 20 per cent., must be regarded only as an estimate.

Alternating Bending.—The specimen rotating (Wöhler). Any one point of the section has a cycle of stress and strain exactly the same as any other point at the same distance from the axis of the specimen. The calculation is founded on the data obtained by measuring the deflexion (under two-point loading) in the plane of the bending couple and also in a plane perpendicular thereto. The latter measurement gives the work done per cycle on the specimen, and this work is equated to the work done on the fibres which have a measured maximum amount of strain at the skin. The error entailed by the use of the usual formula for bending is not less, for the fatigue range of stress, than 8 per cent., and is probably more. Further experimental work on hollow specimens should determine the error within fairly narrow limits. A reduction of 8 per cent. on the 'calculated' stress brings the stress for the fatigue range nearly equal to the proportional elastic limit as observed on the rotating Wöhler specimen. It is possible that the margin of error may depend on the diameter of the specimen ; such scale effect, if any, has not yet been investigated.

REFERENCES.

[1] See 1923 Report, page 23, Professor B. P. Haigh on 'Thermodynamic Theory of Mechanical Fatigue.' Also page 62.

[2] 'Distribution of Stress in round bars under alternating torsion or bending,' pp. 42-43. Report of Complex Stress Committee, British Association, 1923.

[3] *Loc. cit.* p. 54.

VI. The Effects of Inaccuracy of Axial Loading.

By Professor ANDREW ROBERTSON, *D.Sc.*

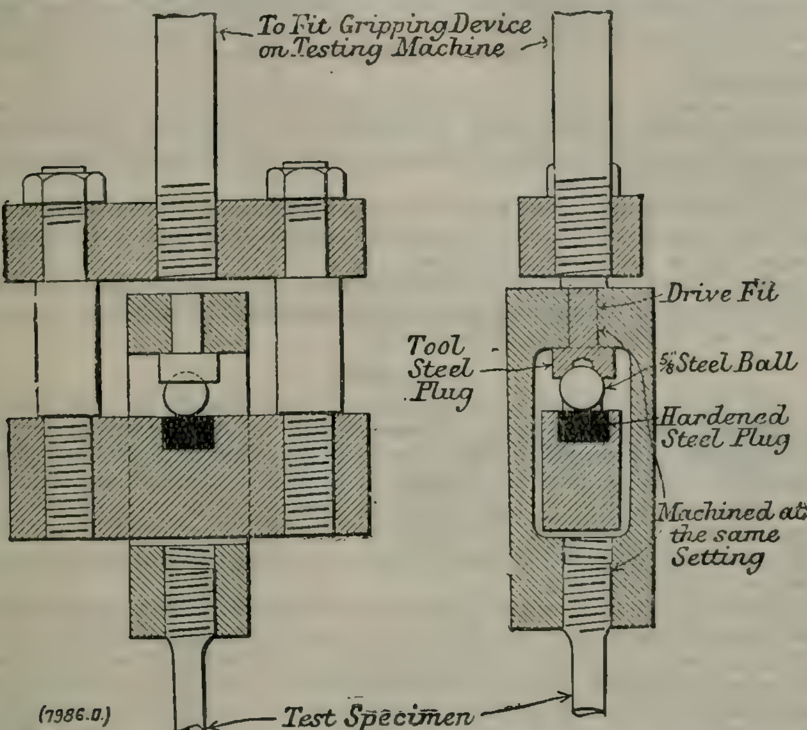
In any experimental work on the behaviour of a material under a particular type of stress, it is always necessary to take precautions to ensure that the desired stress distribution does exist in the portion of the material under investigation. The ordinary methods of gripping specimens even in such a relatively simple case as a tension test do not always secure that the stress across the section is uniform. If to this uncertainty is added a defective method of measuring the strain, it is not surprising that there is oftentimes some uncertainty about the principal elastic properties of materials. It is on record that in one series of tests the value of E for a particular steel was given as varying from $9{\cdot}5\times10^6$ to $65{\cdot}5\times10^6$ lbs. per sq. in. It is the object of this note to consider briefly the effects of the inaccuracy of loading produced by the usual gripping methods, and to indicate devices which materially diminish the errors and so permit of a more accurate determination of the physical properties of the material. The analysis of the variation of stress produced by an eccentric load is of course well known and does not need to be stated here. It is sufficient to remark that with a round specimen of radius r if the eccentricity of the resultant load at any section is αr, the average stress p, required to produce a stress of f, is $\frac{f}{1+4\alpha}$, *i.e.* if the eccentricity is 1 per cent. of the radius, the load p will be 3·9 per cent. less than would be the case with no eccentricity.

Several investigations have been made upon the variation of the strain in a specimen when loaded in tension through the usual wedge or screw grips. Perhaps the most extensive is that of Dr. Scoble (Complex Stress Committee, B.A., 1919), who measured the strain at four places round the specimen. The observations were all very irregular, indicating a very unequal stress distribution, but on taking the mean strain the loads and corresponding strains gave a straight line and thus enabled a value for E to be determined. Using wedge grips the ratio of maximum to mean strain varied from 1·62 to 1·016, whilst with specimens having screwed ends the ratio varied from 1·39 to 1·062. These observations indicate very considerable differences in the stress distribution, and hence one would expect to get values of the elastic limit smaller than the real limit of the material.

In order to diminish this inaccuracy of loading, the author, in conjunction with Mr. Gilbert Cook (now Professor Cook), constructed the axial loading shackles described in 'Engineering,' December 15th, 1911. The construction will be made quite clear by the drawing given in fig. 13, which represents a set which were used to a considerable

extent by the Air Service, particularly for testing aluminium alloys. It is now proposed to give a short account of some of the results that have been obtained using these shackles.

It will be convenient to consider two classes of material, *i.e.* ductile and brittle. The former is characterised by a yield point at which the stress strain diagram is discontinuous, and a stress strain diagram which is practically horizontal at the ultimate. For such materials, therefore, the inequalities in the strain during the elastic region will only affect the elastic limit and the yield (presuming that the mean strain is measured, E would not be affected). Brittle materials, however, have no yield phenomena, and there is no discontinuity in the stress strain diagram, which still has a considerable



The gripping device is shown as used with threaded end specimen. A similar device fitted with split sockets would be used with shouldered specimens.

FIG. 13.

slope at rupture. For such materials one would expect that the ultimate would be affected as well as the elastic limit.

Ductile Materials.

The results of three sets of experiments on different steels are given in Table III. In each case three consecutive specimens were taken in a bar. The two outer ones, Nos. 1 and 3, were tested with ordinary screwed grips, the ends of which were resting on a spherical seating of fairly large radius, and the seating was lubricated in order to get as good a result as possible. The middle one, No. 2, was tested in the special shackles. A typical set of stress strain curves for the large specimens is given in fig. 14. It will be seen that in every case the values of the elastic limit and yield are greater with the special shackles than with the ordinary ones. The disparity is naturally most marked in the case of the small specimens, and the use of these shackles or their equivalent is almost imperative if accurate determinations are to be obtained on small specimens. In every case the same extensometer was used. This was a special one made by the author, but attached to the specimen in the usual way, *i.e.* as in the Ewing or Cambridge, so as to measure the strain in the centre line of the specimen.

Brittle Materials.

In Table IV. are given the results of tests on cast iron and an aluminium alloy (Air Board Spec. L. 5). In the case of the cast iron, two specimens were taken from the same bar, and one was tested in the axial loading shackles and the other in the ordinary shackles with spherical seatings. It will be observed that with the axial loading shackles the elastic limit, the value of E and the ultimate are all higher than with the other shackles.

In the case of the aluminium alloy, the results of the tests are those obtained by another experimenter, and the portions of the broken test-pieces 0·56 in. diameter were sent to the author for re-test. In every case the axial loading tests gave a decidedly higher value, despite the fact that they were on the material at the centre of the specimen, and might reasonably be expected to have shown slightly lower results. It should be noted that this alloy has little or no elongation, so the increase is not due to any strain hardening.

It may also be observed that with these shackles one can test quite small specimens and be sure of getting a good result. The author has a number of records of tests on portions cut from aluminium alloy pistons in which it was frequently necessary to test as small as 0·092 in. diameter.

In this connection it may be noted that several firms had difficulty in getting the required tensile strength for their aluminium alloy, until they used these shackles in accordance with an Air Board instruction.

It is clear, therefore, that for accurate results of elastic determinations and in the case of brittle material of the ultimate also, even in a simple tension test, it is necessary to use some such device as is suggested here.

Compression.

In order to get good stress strain diagrams in compression, the author has used, with considerable success, an apparatus consisting of two long plungers working in a hole in a steel block, from which a portion has been cut away to admit the specimen and its extensometer. The ends of the plungers (hardened steel) are ground together, and each specimen is slightly ground against the plungers before testing. In this way very good tests have been obtained. A complete account of these tests will be found in a paper by the author on 'The Strength of Struts,' published by the Institution of Civil Engineers as a selected paper.

Although this note is concerned only with tension tests, it may not be out of place to direct attention to a number of other cases in practical testing of materials, in which the author has found the usual methods not sufficiently accurate for some purposes and in some cases misleading. Several of these occur in connection with the testing of timber, and an account of the author's researches on this subject is to be found in the Report on Materials of Construction, by Professor C. F. Jenkin, published by H.M. Stationery Office. In particular, reference may be made to this report for details as to the 'Shear Strength of Timber and Beam Tests of Timber,' and to the strength tests of adhesives for timber.

TABLE III.

MILD STEEL.

$\frac{7}{16}$ in. Diameter. Ends $\frac{3}{8}$ in. Gas.

	Tons per sq. in. El. Lt.	Yield	Max.
No. 1 Screwed Ends	8·5	18	24·9
2 Axial Loading	20	20·2	25
3 Screwed Ends	12	18·35	24·8
SPECIAL STEEL 0·421 IN. DIAMETER.			
1 Screwed Ends	26·4	41·4	56·8
2 Axial Loading	34·5	45·8	56·8
3 Screwed Ends	27·4	41·4	55·2
SPECIAL STEEL 0·276 IN. DIAMETER.			
1 Screwed Ends	22·3	—	112·3
2 Axial Loading	28·6	—	112·3
3 Screwed Ends	20·1	—	118·1

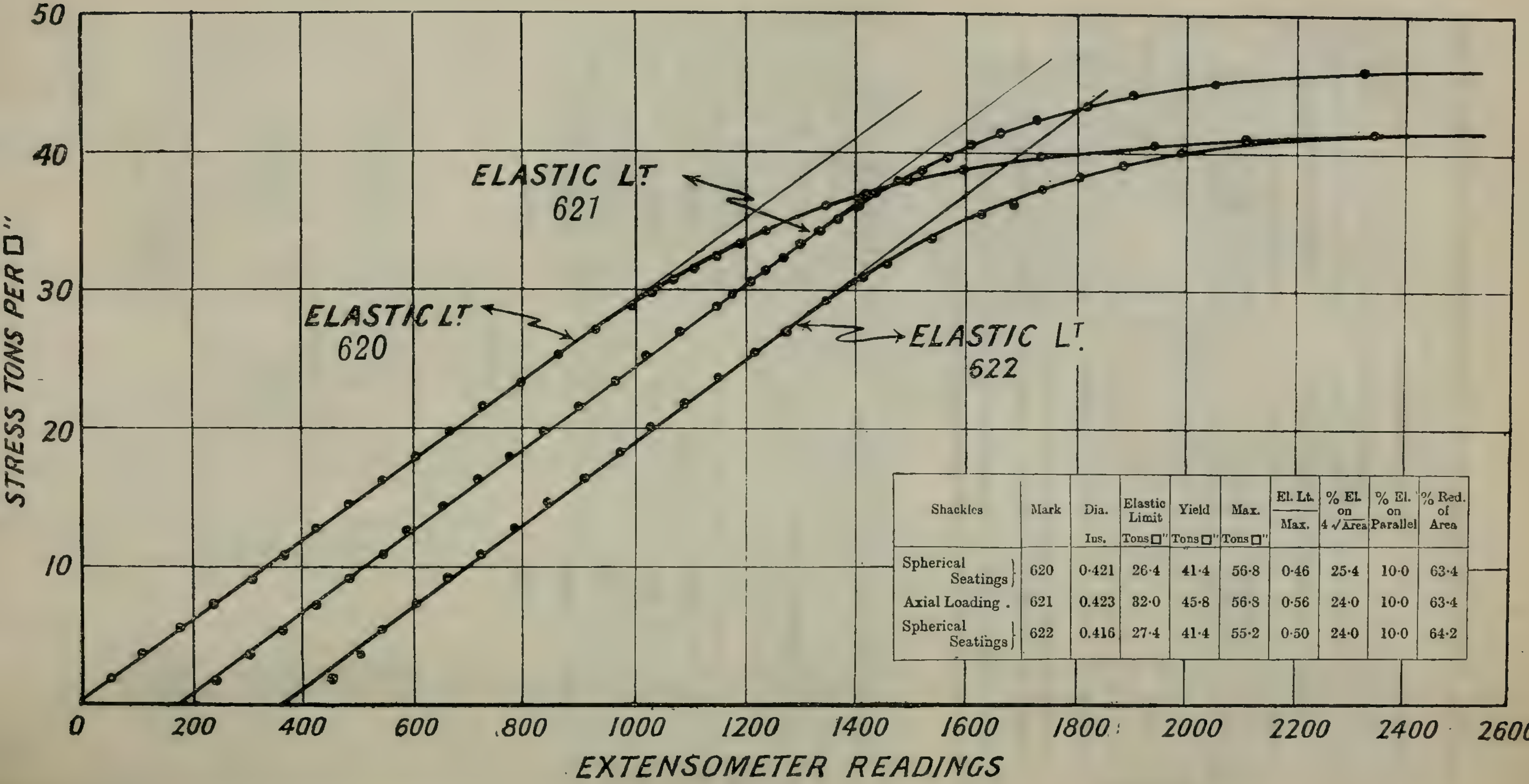
TABLE IV.

BRITTLE MATERIALS.

	Screwed Ends and Spherical Seatings.				Axial Loading Shackles.		
	Dia.	Tons □″ Elastic Limit	Tons □″ Rupture	E	Tons □″ Elastic Limit	Tons □″ Rupture	E
Cast Iron.	·500	—	11·4	—	2·7	12·6	—
	·426	2·5	10·5	5180	2·5	12·00	6110
	·430	1·23	11·1	5320	1·54	11·1 [1]	6230

[1] Broke at gauge centre pop.

	Screwed Ends and Spherical Seatings.	Axial Loading Shackles.
	Rupture. Tons □″	Rupture. Tons □″
Aluminium Alloy.	11·63	11·73
	11·80	13·48
	10·60	12·66
	11·02	13·62
	12·00	14·35
	10·40	13·80



Shackles	Mark	Dia. Ins.	Elastic Limit Tons □"	Yield Tons □"	Max. Tons □"	El. Lt. / Max.	% El. on $4\sqrt{\text{Area}}$	% El. on Parallel	% Red. of Area
Spherical Seatings	620	0·421	26·4	41·4	56·8	0·46	25·4	10·0	63·4
Axial Loading .	621	0.423	32·0	45·8	56·8	0·56	24·0	10·0	63·4
Spherical Seatings	622	0.416	27·4	41·4	55·2	0·50	24·0	10·0	64·2

Fig. 14.

VII. On the Drop of Stress at the Yield Point of Ductile Materials.

By Professor Andrew Robertson, *D.Sc.*

In the ordinary testing of a ductile material the yield point is indicated by the sudden extension of the specimen, and the drop of the beam of the testing machine. Autographic load extension diagrams also indicate that the load immediately after passing the yield is less than that required to initiate it. The author, in conjunction with Mr. Gilbert Cook (now Professor Cook), investigated the phenomenon in some

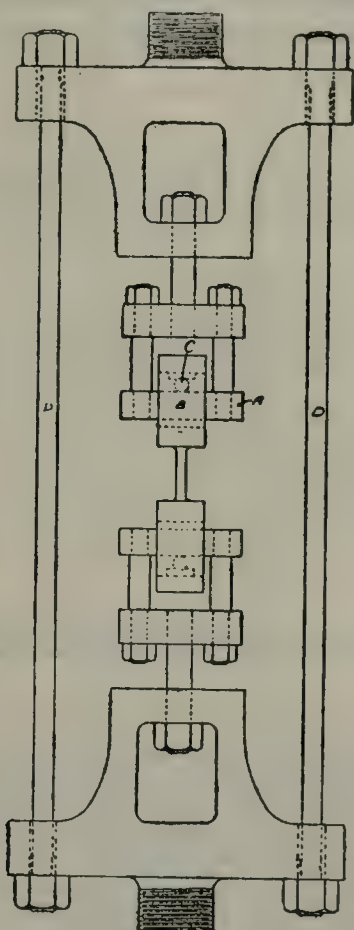


Fig. 15.

detail in a paper published in the 'Proceedings of the Royal Society, 1913.' By taking special precautions to secure axial loading and to limit the strain after the initiation of the yield, it was found that the reduction of stress was of the order of 25 per cent. for the particular steel used. The principle of the apparatus will be clear from fig. 15.[1] The two outer bars D are provided with extensometers and the specimen under test is loaded through special axial loading shackles. The total load is shared by all three, and if the load in the centre one is reduced by reason of a 'drop' at yield, the load on the outer ones is increased. It was further found that after yield had occurred, and the load removed and again applied, the stress required to continue the yield was the reduced stress. This is shown in the diagram in fig. 16.[2]

Further evidence in support of this large value was found in the behaviour of the same mild steel under uniform bending, and also under torsion. By assuming that after yield the outer layers only sustain a uniform stress less than that required to produce yield, and that the inner layers are still elastic, it was found possible to reduce to a very simple form the relation between the applied moment and the deflection, or twist in the case of torsion. The curves, corresponding to various values of the drop of stress, were plotted, and it was found that in the case of bending the experimental points agreed fairly well with the curve for the assumption of a drop of about 25 per cent. In the case of torsion the formula showed that with the drop of 25 per cent. the moment which the specimen could sustain was exactly equal to that required to initiate the yield. In the experiment it was found that this condition was nearly realised, for when the yield point was reached the angular displacement increased at a slow but uniform rate under the same moment. For the particular steel tested, therefore, the

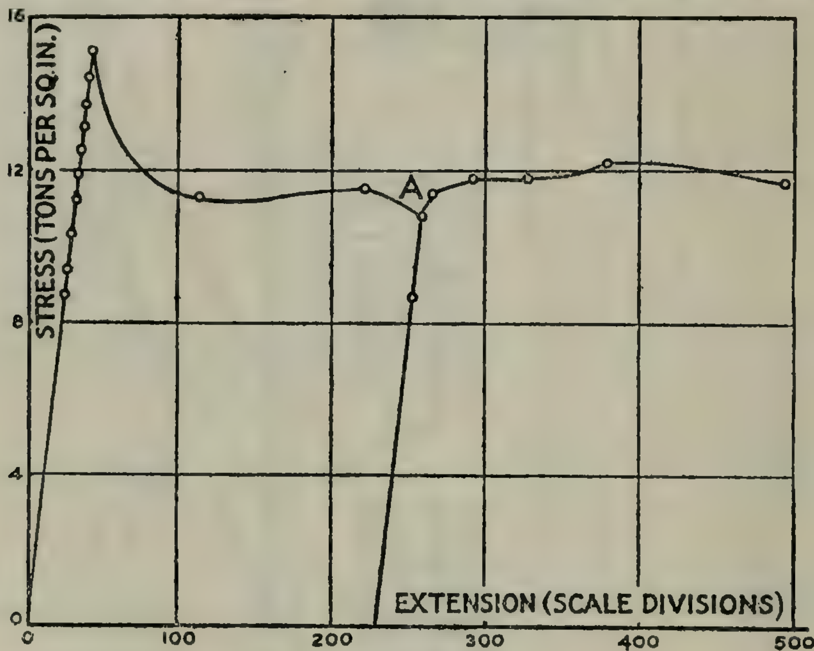


FIG. 16.

yield penetrated right through the specimen, and was not simply confined to a few outer layers. Since these experiments were carried out the author has investigated the same phenomenon in compression. The results are described in detail in a paper on the 'Strength of Struts,' published by the Institution of Civil Engineers. Briefly, it may be stated that wrought iron, mild steel, and a 36-ton structural steel all show a pronounced drop of stress at yield in compression, but the amount is not so great as in tension ; *i.e.* wrought iron 7·3 per cent., mild steel 7·5 to 22 per cent., 36-ton structural steel 5·9 per cent. Bright rolled steel, however, shows no real pronounced drop, the stress diagram merely changes its slope very considerably at the point that would usually be regarded as the yield, *i.e.* the diagram is like that of an overstrained specimen. The material, however, when annealed does show the characteristic drop at yield of mild steel.

It is the object of this note to consider briefly the bearing of this phenomenon on several cases of stress distribution.

Strength of Struts of Ductile Material.

If a strut is axially loaded, and the load across the section is uniform, it is clear that if any portion of the section yields, and there is a reduction of stress, the resultant of the stress no longer passes through the centre of the specimen. There is, therefore, a bending moment introduced which still further intensifies the unequal stress distribution produced by the yield, and complete collapse is inevitable. In struts of commer-

cial sections, if the load is applied at the ends in the manner adopted by most experimenters, the stress will not be uniformly distributed owing to slight curvature of the specimen and eccentricity of loading. By assuming that a portion of the heavily stressed side only sustains a strain less than the yield, it is possible to calculate the new position of the resultant of the stresses. If the new position is such that the bending moment is increased, then complete collapse is inevitable. It is found that with mild steel this will occur for all struts having $\frac{L}{K}$ (ratio of length to radius of gyration) less than about 85. That is to say, taking Tetmayer's test results of mild steel, and determining the eccentricity of the load at the point of failure for a sturt having $\frac{L}{K}$ less than 85, complete collapse would occur if the stress on the concave side reached the yield. In cases where the eccentricity is greater, complete collapse would not necessarily occur immediately, though the specimen would be overstrained and permanently bent. Thus in all tests on struts which are deliberately loaded eccentrically it is found that in the region where the eccentric effects are most marked, *i.e.* $\frac{L}{K}$ less than 80, the struts do sustain more load than would be calculated on the basis of the maximum stress being equal to the yield. In these cases, however, the direct stress is small and the bending stress high, so that the conditions approximate more closely to a beam test. These considerations fix the yield point as the maximum stress that a strut reasonably accurately loaded will sustain.

On this basis the author has examined all the important series of strut tests, and has found that they can all be represented extremely well by the equivalent curvature formula first proposed by Professor Perry, but using the yield as the maximum stress term. For a full discussion of these results, and for some tests on eccentrically loaded struts, reference should be made to the author's paper on the 'Strength of Struts' published by the Institution of Civil Engineers.

For materials that have no yield (as defined by a drop of stress) but only a more or less well-marked point at which a rapid change of slope of the stress strain diagram occurs, the collapse is not so sudden, and struts will sustain greater stresses than the 'yield.'

In the particular case of cast iron the author has found very good agreement with Southwell's[3] formula, and in one case of bright rolled steel and in another of a sample of duralumin a fair approach to this formula.

Ultimate Strength of I *Beams of Ductile Materials.*

The strength of I beams is another case in which the attaining of the yield stress at any point corresponds to the ultimate strength of the specimen. The stress distribution just before yield is reached may be assumed to be linear, but after yield there will be portions on both flanges which sustain only the reduced stress. This will obtain for very great deflection, for it is not till the plastic strain is many times the elastic strain that the specimen again sustains the yield stress. In these yielded regions the stress is practically uniform. The inner portion which has not yielded will be elastic. Suppose we assume that the tension and compression flanges behave in the same way, and calculate the reduced stress, which applied over the whole flanges will just give, together with the moment of the web (which is assumed still elastic with a maximum stress equal to the yield), the same moment as that required to initiate the yield. To simplify the analysis we will take a 10 in. × 5 in. section, having webs 0·4 in. thick and flanges 0·6 in., and assume a yield of 18 tons per sq. in. For this section it is found that if the drop of stress is about 8 per cent., the moment is only just equal to the moment required to produce the yield on the outer layers. This is much less than the magnitude of the drop found in several steels, so we should not expect that this I beam would stand more than the moment that will produce a stress at its surface equal to the yield. A number of tests on I beams have been carried out by Professor H. F. Moore,[4] and in all the cases where the failure was by primary flexure it was found that the computed fibre stress at the maximum applied load was generally slightly greater than the yield. In the seventeen tests recorded, the average ratio of maximum stress to yield stress was 1·07, varying from 1·01 to 1·18. In these tests it is probable that the yield is somewhat higher than that given, as the method adopted for loading the compression specimens would not ensure a uniform distribution of stress. It is

therefore clear that with I beams of ordinary section the maximum stress that can be applied is the yield stress.

This point is also of great importance in timber used for aeronautical work. All timbers in the air-dry condition show a marked drop of stress at the ultimate. Spruce, for instance, when tested in compression has a drop of 20 per cent. If therefore these timbers are used in the form of I beams, the maximum moment which they can sustain is determined by the compression yield stress despite the high value of the tensile strength of timber. It is for this reason that the use of the term 'modulus of rupture' in timber tests gives a misleading idea of the strength when used as I beams. The results of some uniform bending tests on spruce are given in Table V. Four specimens, 3 in. × 1½ in., from the same plane were taken, and two (Nos. 1 and 2) were tested as solid beams. Specimen No. 3 was made I section with flanges 0·8 in. thick for about 3 in. in the centre, the rest being solid, and No. 4 was also made I section but with flange 0·4 in. The elastic limits, modulus of rupture, and the results of a compression test on a sample from the end of the actual specimen are given. It will be seen that whereas the ratio of the modulus of rupture to the compression ultimate stress is about 1·56 for a solid specimen, it is only about 1·1 for a section with flanges 0·4 in. thick. The use of the modulus of rupture as calculated from the solid section would therefore be misleading. It may be also noted that the results of a large number of tests on actual aeroplane spars all showed that no spar would stand a load appreciably greater than that which produced the faint white line which characterises compression failure in spruce.

Complex Stress Distributions and Fatigue.

In ordinary structural work, involving the use of rivets, the stress distribution in the material round the rivet holes is very complicated, and the maximum stress is often much greater than the mean stress, provided the material is elastic. Using a material which has a drop of stress at yield, however, we have for some types of stress cycles a kind of safety valve, for the material will simply flow at any place where the stress exceeds the yield, and transfer some of the load on to the under-stressed material. For a single application of a load there is no doubt that this does occur, for the ultimate tensile strength of a bar of mild steel with a hole in it is always greater than the area of the section multiplied by the ultimate strength of the material. This is due to the yield phenomena, and also to the effect of the surrounding material in diminishing the lateral contraction. With a hard steel, however, this does not occur, and the stress concentrations reduce the strength.

In the case of simple pulsations of stress (*i.e.* variations between two values both of which are tension) on a specimen without stress concentrations, the upper limit for a material which has a drop of stress at yield is probably always above the yield. One would therefore expect that the stress concentrations due to the presence, say, of a hole would have little effect on the fatigue limits; certainly nothing like the variation suggested by the mathematical analysis (*i.e.* about 3 to 1). This appears to be substantiated by Professor Haigh [5] and Mr. Wilson's experiments. They state that, for the mild steel they used, the stress concentration due to the presence of holes appeared to have little effect on the limit for pulsating stress. The test proved that for the particular material tested, 'in spite of stress concentration, a stress closely approaching the yield stress was necessary to fracture by fatigue.'

For materials, however, which have no drop of stress at yield, say hard drawn steel, the upper fatigue limit for pulsating stress may be less than the yield, and it is probable that stress concentrations may have a very marked effect. In another part of this report Professor Haigh describes experiments which show that for a sample of hard drawn steel the effect is very marked, though not quite to the extent suggested by the mathematical analysis. It is hoped that they will continue this work and test other steels, particularly those with high yield points.

The use of a material with a drop of stress at yield appears to be essential for structural work, and any methods of fairing holes which destroy this property, say by seriously overstraining the material near the hole, are to be strongly condemned. In the abstracts from current periodicals prepared by the Institution of Civil Engineers (January 1924) there is given an account by Füchsel of the failure of a gusset plate due to the serious overstraining of the metal round the hole, presumably through excessive drawing by means of a drift.

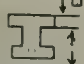
In the case of complete reversals of stress the upper fatigue limit will be below the yield of the material, and there is reason to suppose that the stress concen-

trations will have pronounced effects. There is, however, little available information to enable one to decide if a material with a drop of stress at yield possesses any advantage over other materials which have not this property. According to Stanton,[6] who tested various samples of steel having sharp corners and therefore stress concentrations, a steel with a low carbon content realises a larger percentage of its maximum resistance than does steel with a higher carbon content. The lower carbon steel is the one which will have the greater drop of stress at yield. It thus appears that in this connection also the drop of stress at yield is indicative of a property which it is highly desirable that materials of construction should possess. It is hoped that further experimental work on the fatigue of specimens with stress concentrations will be undertaken.

REFERENCES.

1 See *R. and C. Proceedings Roy. Soc.*, p. 463.
2 See *R. and C. Proceedings Roy. Soc.*, p. 465.
3 Southwell, *Engineering*, August 23, 1912.
4 University of Illinois. Bulletin 68.
5 B.A. Stress Committee Report. 1923.
6 Stanton, *Engineering*, April 19, 1907.

TABLE V.

Mark	Section	Approx. Dimensions	Uniform Bending		Compression	$\frac{fr}{fc}$
			Elastic Limit	Modulus of Rupture, *fr*	*fc*	
			lbs. □″	lbs. □″	lbs. □″	
1		3″×1·5″	4,550	6,560	4,200	1·56
2		,,	4,550	6,560	4,640	1·42
3	 0·8″	,,	5,000	5,550	4,500	1·23
4	 0·4″	,,	5,300	5,600	5,110	1·10

1 R. V. Southwell, *Engineering*.
2 Strength of I Beams by Flexure, *Bulletin* 68, University of Illinois.
3 B.A. Stress Committee, 1923.
4 Stanton, *Engineering*, April 19, 1907.

VIII. Note on Impact Experiments.

By R. V. SOUTHWELL, *M.A.*

In the progress of engineering science, a steady improvement in the quality of the materials which the metallurgist can supply is accompanied by an equally continuous increase in the stringency of the demands which are made upon them by the designer; and as a consequence new tests come to be needed, for ensuring that a material does in fact possess the properties desired. But the problem of devising a suitable test is, in general, far from simple—not only because it is difficult to form an exact notion of the property in question (as is shown by the vagueness which still attends the definition of 'hardness,' 'toughness,' 'ductility,' and the like), but also because it is almost impossible to achieve conditions of testing such that this property has a predominant influence on the results. Hence it comes about that many tests are current in engineering practice to-day which, although they serve in a general way to discriminate between 'sound' and 'unsound' material of a given class, are very difficult to interpret with precision, as indicative of some definite physical quality.

Many examples could be given, but perhaps the best is afforded by the 'Notched-bar Impact Test,' of which the early history has been recounted by Stanton and Batson in a recent paper.[1] Originally devised by Barba as a method of detecting brittleness in steel, and subsequently developed by Charpy, Izod, and others, this has come more and more into favour as a means of determining the 'toughness' of a material, by which is meant its ability to resist fracture by sudden shock. And, as its use has extended, the need of standardisation has become more imperative; but against this standardisation has always been the objection that very variable results are given by different individual tests of the same material. Moreover, it has been urged that 'the conditions of test are highly artificial in comparison with the conditions of practice, and that the results depend not only on the shape of the notch but also on the actual size of the specimen,' so that 'there is no certainty that the relative impact resistance of two materials as given by tests on a notched specimen of standard dimensions has any relation to the relative impact strength of the materials in a loaded structure.'[2]

In this country the most common form is the Izod test, in which the specimen is held by a vice at one end and struck at the other by a falling pendulum; but abroad the Charpy test is more generally employed, in which the specimen is supported horizontally at its ends on knife edges of given form, and struck in the centre, opposite the notch, by a pendulum. Stanton and Batson, holding the view 'that, although standardisation of the method of test and of the dimensions of the specimen was very desirable, such standardisation was to be deprecated until a clearer interpretation of the test had been attained,' began in 1913 a careful study of the dimensional effect in such tests, the proposal being 'to carry out a large number of impact tests in which geometrical similarity as regards both form of specimen and testing appliances should be preserved.'[3] This work, after frequent interruptions during the period of the war, was brought to a conclusion in 1920, and reported in the paper cited above. Notches of the standard Charpy form, and also V notches having an angle of 45°, were tested, and in each case an important dimensional effect was observed—the energy absorbed in fracture, per cubic centimetre of the specimen, falling steadily as the dimensions of the specimen were increased: the serious implications of this result, in regard to the value of the test as an absolute indication of 'toughness,' were pointed out, and the conclusion was drawn that 'the value of the impact test lies, not in discriminating between the impact resistances of different materials, but as a means of ensuring that the impact strength of any given material is at its highest.'[4]

In a note[5] communicated to the Aeronautical Research Committee, I endeavoured to examine these results in the light of dimensional theory. I showed, 'on the assumption that the occurrences at fracture, for a given quality of material, are completely determined by the velocity of striking, and by the dimensions of the specimen and apparatus (the material of the apparatus being kept the same throughout, so that the mass of the striker varies as the cube of its linear dimensions), that the energy of fracture per unit volume should be a function only of the striking velocity, provided that the stress p at which fracture begins is an absolute constant of the material; but that the energy may vary with the dimensions of the specimen, if p depends in addition upon the rate of straining.' Thus it appeared that there is a possibility of scale effect in material characterised by what may be termed 'solid viscosity,' but not in others; and I was informed by Dr. Stanton that this theoretical conclusion is in general agreement with his experimental results, since he found that the impact figure, for a constant velocity of striking, varied with the absolute dimensions of the specimen and apparatus in the case of ductile materials such as mild steel, but not in the case of brittle materials, where the distortion of the specimen before fracture was comparatively small.

If this application of dimensional theory is legitimate, it will follow that the results of impact tests conducted on specimens of varying size but of similar proportions, and with apparatus in which geometrical similarity with the specimen is maintained, should enable us to classify materials under the two headings of materials which exhibit 'viscosity' and those which do not. And if confirmed by experiment these conclusions would not be devoid of practical significance since they indicate the importance, in the determination of 'impact figures' for materials which come under the first heading, of standardising not only the shape but also the dimensions of the specimen and apparatus; for materials of the second class, only the shape would appear to be important.

But the conditions of test must be such that geometrical similarity is maintained in the apparatus as well as in the specimen, and I pointed out that it is doubtful whether

apparatus of existing design could not be improved, more particularly as regards the satisfaction of this requirement. 'The problem is an exceedingly intricate one, but its essentials clearly consist in a rapid development of stress resulting from propagation through, and reflection at the surfaces of, the specimen, striker and apparatus. The application of dimensional theory requires that the presumed geometrical similarity shall extend to all parts of the system into which the stress is propagated, and we know from elastic theory that the two principal velocities with which stress is propagated through steel are of the order of 17,000 and 10,500 ft. per second. Now the time of fracture, according to the Table given on p. 94 of Dr. Stanton's and Mr. Batson's paper, ranges from one- to four-thousandths of a second, and in such time the faster wave would travel a distance of from 17 to 70 ft., so that many reflections of stress must have occurred during the process of fracture. Reflections of stress are, of course, taken into account by the dimensional theory, so long as absolute similarity of the specimens and apparatus is maintained; but is it certain that this condition has been realised hitherto in every part of the apparatus which lies within 70 ft. of the point of impact? It seems probable that much of the measured "work of fracture" will have been propagated through the swinging arm (which is very stiff) into parts of the apparatus, or even into the ground, where it will be lost by dissipation, and that this "missing quantity" of the experiment will not be a constant fraction of the whole, but will depend upon the time of fracture—*i.e.* upon the striking velocity.'[6]

To obviate the danger of inaccuracies arising from this cause, I suggested that the apparatus ought to be designed with the definite aim of confining the total energy to the specimen, striker and anvil—the two latter parts being kept strictly to scale. 'All that seems necessary, in order to attain this object, is to design the striker and anvil as elongated bodies which can be slung like a ballistic pendulum so as to move without rotation, and to arrange that, in both, the force of impact acts at the centre of gravity, in a direction perpendicular to that of the suspensions. Practically no energy should then be transmitted through the suspending chains or cords, owing to their complete flexibility, and the total energy lost at impact could be determined by measuring the swings of both striker and anvil.'[7]

Further consideration has convinced me that the chances of consistent results would be greatly improved if the use of a notched bar as a means of concentrating stresses were discontinued, and apparatus constructed for applying an impulsive torsional couple to a specimen of 'hour-glass' form. Such a specimen could equally be relied upon to fracture at the waist, but the distribution of stress at fracture would be immensely simpler, and in fact should be calculable with fair approximation. Provision must be made, as before, for confining the total energy of the test within the specimen and apparatus, but this should not be a difficult matter.

For example, the apparatus might consist of two lathe headstocks, mounted on the same lathe bed, and each carrying a heavy chuck. Both spindles must be free to turn, and the specimen would be held at one end within the jaws of the first chuck, whilst its other end, at the commencement of the test, ran freely within the jaws of the second—this second chuck being initially stationary and not tightened up, but provided with means for producing a sudden engagement of its jaws with the free end of the specimen. The test will then be conducted as follows: The first chuck, holding the specimen, is run up to any required speed, and left spinning freely. The second (stationary) chuck is then suddenly engaged with the free end of the specimen. Its resistance to sudden acceleration brings an impulsive torsional couple to bear on the specimen, which breaks at the waist. The energy of fracture can be calculated as the difference between the total kinetic energies of the system before and after fracture.

The foregoing description is, of course, merely a sketch of the essential features of the test proposed; it introduces several problems of practical design which may take considerable time and trouble to solve. I hope that it may be possible in the near future to investigate these systematically.

REFERENCES.

[1] 'On the Characteristics of Notched-bar Impact Tests.'—*Proc. Inst. C.E.*, vol. ccxi. (1921), pp. 67-100.

[2] *Loc. cit.*, p. 71. [3] *Loc. cit.*, p. 71. [4] *Loc. cit.*, p. 79.

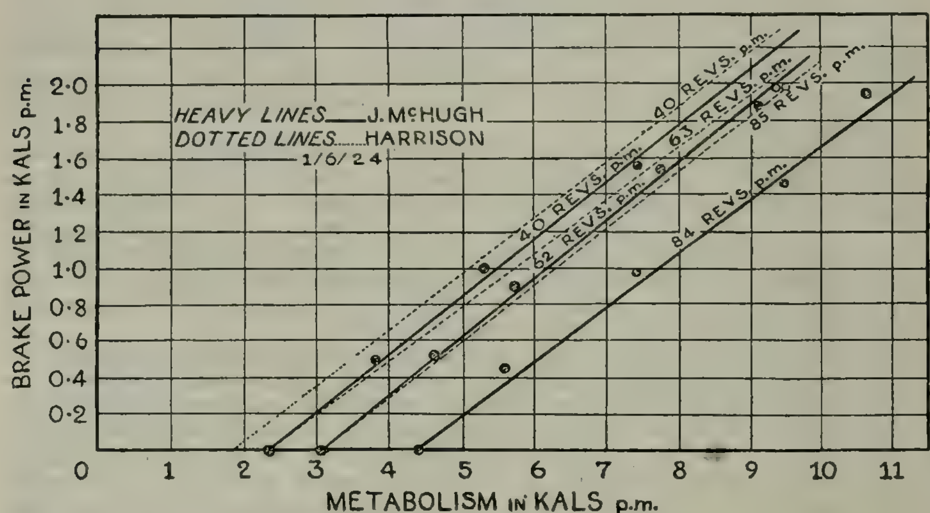
[5] Aeronautical Research Committee, R. & M. No. 732 (1921).

[6] *Loc. cit.*, p. 8. [7] *Loc. cit.*, p. 8.

Cost of Cycling at Varied Rate and Work.—*Report of Committee* (Professor J. S. Macdonald, *Chairman*; Dr. F. A. Duffield, *Secretary*). (*Drawn up by the Secretary.*)

Employing the experimental procedure indicated in last year's report of the British Association[1] the research on the 'Cost of Cycling at Varied Rate and Work' has been carried out throughout the year, and data from the subject 'Harrison,' there alluded to, have been amplified to provide a series of figures representing the metabolism of cycling at three different rates—*i.e.* forty, sixty-three and eighty-five revolutions a minute. On the bicycle ergometer, with the rope-brake acting on the hind-wheel, mechanical work was performed at five selected levels—0, ·05, ·10, ·15, and ·20 h.p.—the lowest being obtained without the application of a brake, and therefore simply represents the 'cost of movement'[2] alone, with possibly a trifling allowance to be made for the internal friction of the cycle.

These results and also those upon another subject (J. McHugh)—already communicated to the Physiological Society[3]—appear when plotted as three straight lines: the dotted ones represent the results upon Harrison and the unbroken thick lines those upon McHugh. The ordinate is the brake-power in Kals per minute, and the abscissa the metabolism in the same units, calculated from the respiratory exchange.



In both cases it is clear that a certain expenditure of energy is involved in the movements of the limbs, and is represented in the chart by the distance measured along the abscissa from the zero to the point where the particular line cuts it. A further expenditure, indicated by the slope of the lines, represents the performance of external work. For each subject the metabolic expenditure is directly proportional to the external work done, and the efficiency therefore is constant, not only at one rate but at all rates, since the lines are practically parallel. The position of the lines on the abscissa is indicative of a considerable difference in the cost of movement in the two cases, and as far as these two subjects are concerned it is less with the subject of smaller body weight (Harrison 64·4 Kgm., McHugh 74·2 Kgm.), a conclusion previously arrived at and elaborated by Professor J. S. Macdonald in his 'Man's Mechanical Efficiency in Work Performance.' Another person on whom work is still being continued, has yielded somewhat unexpected results; for although his body weight is only 51 Kgms. his figures lie intermediate between those of Harrison and McHugh. Whether this peculiarity is capable of some other explanation or whether there is an optimal weight for movement is a question which will necessitate further work before any decision is arrived at.

And again, regarding the comparative efficiency of different subjects performing these particular experiments, a definite statement on this point must be deferred until data from a greater number of individuals are available.

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[1] F. A. Duffield—Cost of Cycling at Varied Rate and Work. *Rep. Brit. Assn.*, p. 481 (1923).

[2] J. S. Macdonald. *Proc. Roy. Soc.*, B., vol. 89, p. 403 (1916).

[3] F. A. Duffield and J. S. Macdonald. *Proc. Journ. of Physiol.*, vol. lviii., p. xiii (1923), and vol. lix., p. xvii (1924).

Educational Training for Overseas Life.—*Report of Committee appointed to consider the educational training of boys and girls in Secondary Schools for overseas life* (Rev. Dr. H. B. Gray, *Chairman*; Mr. C. E. Browne, *Secretary*; Dr. Vargas Eyre, Sir Richard Gregory, Mr. O. H. Latter, Sir John Russell).

INTRODUCTORY NOTE.

In recent years the congested state of the various professions and industrial occupations in Great Britain has presented a serious problem alike to parents and educational authorities. Boys on leaving our secondary schools are finding it more and more difficult to obtain suitable openings in offices or works, and though a number enter banks or insurance offices, they represent only a tithe of those competing for a place. On the other hand, the overseas Dominions possess vast resources awaiting a population to develop them. They need workers for the land, and offer great opportunities to lads of spirit and enterprise. In spite of tempting offers by the overseas Governments in the form of free land and loans, few boys from our public schools, or from other large secondary schools, are found to be taking to colonial life. Various reasons may be advanced to account for this reluctance, or absence of desire on the part of English boys to go overseas, but whatever they are the effect is the same—a distinct loss to the Empire generally and a source of weakness to the home country particularly.

While a boy is at school the problem of his future career seldom troubles him; he is content to wait on opportunity when school days are over. Few boys up to sixteen have any definite ideas or desires on the subject. Unless their parents or friends have places already marked out for them, they tend to follow some prescribed course of study leading up to such examinations as offer certificates qualifying for entrance into the various professions or into commercial life. Thus the school curriculum very often determines a boy's career. In the case, however, of the many boys who show no power or liking for any special school-subject, their future occupation depends often on some chance opening. Banks and other offices are full of such young men, yet many of these would from their character and physical qualities be far better suited for the more vigorous and freer life on the land overseas.

PURPOSE OF COMMITTEE.—It is very significant that the majority of head-masters think some of their boys would have done better in life on the land overseas than in the occupations they have taken up in England. Several headmasters emphasise this point and put the number of such boys as high as 10 per cent. of those leaving school each year.

At the Headmasters' Conference in December last, emphasis was laid on the need for a scheme of settlement on the land, and a resolution was passed instructing their committee to investigate the possible methods of encouraging and organising the settlement of public school boys in the overseas Dominions.

The Headmaster of Wellington, in moving the resolution, said: 'It is a healthier, more human, and a more useful life to be growing wheat or wool for the needs of man in the wind, sunshine, and rain than to be calculating percentages under electric light, and with all the advantages of central heating. We ought to be doing more than we are in encouraging boys to go out. I am not certain that many of us have done anything to familiarise them with the idea that to go overseas is a natural and ordinary conclusion of public school education.'

Many schools send one or two boys a year to agricultural colleges or to farms, but in the majority of cases they are not trained there specifically for overseas life.

About 12 per cent. of the schools have sent one or two boys yearly out to Australia, New Zealand, or Canada.

The inquiry undertaken by this Committee was suggested by the fact that very few boys seem to have entertained the prospect of a career in agricultural occupations. Its object has been to find out to what extent provision is made in secondary schools for developing a boy's natural bias towards life on the land, or for giving girls some practical training in those modern operations associated with farm life.

This inquiry has been carried out mainly by means of a questionnaire addressed to the headmasters and headmistresses of some 500 secondary schools (see page 357).

Information has also been sought from the Board of Education as to any reports that may have been previously issued on the subject, from Directors of Education or Chairmen of Higher Education Sub-Committees of various counties, and from Directors of Education in the overseas Dominions as to their opinion on what might be done in our schools to prepare boys and girls for overseas life. Various institutions, such as the League of Empire, Public Schools Employment Bureau (Overseas Section), Victoria League, Overseas Settlement Office, have also been informed of our inquiry, and suggestions and opinions have been invited.

In a prefatory note to the questionnaire, the Committee pointed out that there are to be found in most schools a percentage of boys and girls whose capacities would be better developed by the study of the principles underlying agriculture, or related subjects, than by more academic studies in literature, mathematics, and science. Practical work on the land and the introduction of agricultural problems in the science laboratory would awaken their interest and stimulate their activities. The provision of such opportunities, it is believed, would lead to better work in other subjects which hitherto had not appealed to many boys or girls. Moreover, it would bring home to their minds the possibility of a career in one of the Dominions overseas more suited to their temperament and ability than any which the restricted opportunities in the home country could possibly offer.

The Committee invited expressions of opinion from headmasters and other authorities who have had experience of providing school occupations for boys and girls from the age of fifteen upward as to (1) the advantage of allotting part of the school hours to a plan of work in which, though the outlook is vocational, the training is really educational; (2) the practicability of introducing a scheme where work on the land forms part of the school curriculum, at least for a section of the school, or in the absence of any facilities for such operations, the practicability of giving to the manual instruction, and work in the science laboratories, a distinctly agricultural bias.

The Committee wish to express their cordial thanks to those headmasters and headmistresses who assisted the work of inquiry by answering the questionnaire, and to the various secretaries and Directors of Education who contributed of their experience, suggestions, and opinions on the problems presented. Particularly do they wish to acknowledge the valuable contribution made by Canon Sewell, Chairman of the Gloucestershire Higher Education Sub-Committee, and that by the Director of Education for New Zealand.

I. BOYS' SCHOOLS.

The following is an abstract of the replies received to the questionnaire from 296 secondary schools in England, Scotland, and Wales, to the headmasters of which copies were sent.

The questionnaire opened with the inquiry (1) whether the school had considered the question of introducing into the school curriculum practical work on the land to meet the needs of those boys referred to in the prefatory note; (2) whether any such scheme had been adopted and, if not, (3) what were the possibilities of a scheme being introduced in the near future, or what reasons would prevent such developments?

Replies were received from 156 schools which may be classified as follows:—

A. Those schools in which the question of agricultural work as part of an educational training for certain types of boys has been considered, and in which a scheme of some kind is already in operation. Number of schools, twenty-four. Of these, eight have a definite agricultural scheme as part of the school curriculum for all boys—viz., Abbotsholme, Derbyshire; Bedales, Petersfield; Brewood Grammar School, Stafford; Hanley Castle Grammar School; Intermediate School, Welshpool; Knaresborough Rural Secondary School; Shepton Mallet, Somerset; Wem Grammar School, Shrewsbury. Seventeen schools have a definite agricultural scheme for a section of the school only—viz., Ackworth, Yorks; Beccles; Christ's Hospital, Horsham;

Dauntsey School, Wilts; *Eton; *Harrow; Hawarden County, Flint; Market Drayton Grammar School; Oundle; *Paston, N. Walsham; *Repton; *Sherborne; *Stamford School; *Friends' School, Great Ayton; Leeds Boys' Modern School; Sexeys; *Leeds Central High School.

N.B.—* These schools have not any field work in their scheme, but visits to neighbouring farms are arranged for in most cases.

B. Those schools in which the question has been considered, and in which the idea has been favourably entertained, but at present difficulties of staff, finances, &c., have prevented the actual introduction, although an agricultural bias has been given to some of the work in science and manual classes. Number of schools, thirteen :—Beverley Grammar School, Yorks; Berkhamsted; Brighton Municipal Secondary School; Caterham School, Surrey; Glenalmond; Hymer's College, Hull; Manchester Grammar School; Perse School, Cambridge; Roan School, Greenwich; Tonbridge; Westminster; Orphan School, Cheadle Hulme; Christ's College, Finchley.

C. Those schools in which the matter has been considered, and whose headmasters either do not express an opinion or are not in favour of introducing any practical work in agriculture into the curriculum. Number of schools, three :—Bournemouth, Leeds Grammar School, and Oakham.

D. Those schools in which the problems as presented by the questionnaire have not hitherto been considered, but the headmasters of which express themselves in favour of a scheme of practical work, and would introduce it when circumstances make it possible. Number of schools, twenty-two :—Almondbury, Yorks; Bishop's Stortford; Doncaster Grammar School; Glasgow High School; Hamilton Academy; King Edward School, Stourbridge; King Edward VI. Grammar School, Bury St. Edmunds; King Edward VI., Chelmsford; Kingswood, Bath; Manchester Central High School; Municipal Secondary School, Swansea; Plymouth Corporation Grammar School; Ryhope, Durham; Friends' School, Saffron Walden; Silcoates, Wakefield; Strand School; University College School, London; Hurstpierpoint College; St. Olave's; Colston School, Bristol; Crewkerne, Somerset; Leighton Park, Reading.

E. Those schools in which the matter has not been considered, and whose headmasters (1) are opposed to, or see no reason for adopting, any such scheme for even a section of the school; (2) offer no opinion for or against such; (3) state that the situation of the school in urban or in industrial centres precludes any consideration of the matter.

Number of schools, ninety-one. In some cases difficulties arising from staff, finances, and school organisation were frequently offered as obstacles in the way of adopting any practical work on the land.

PARENTS' ATTITUDE.—Very few headmasters seem to have received from parents or boys any spontaneous expression of desire for farm work at school, although where such work has been provided, the boys have usually been very keen to join the 'farm' class.

In one case it is stated 'some parents send their sons to this school on account of the special facilities offered for agricultural education in the higher forms.'

In several replies it is stated that parents are opposed to their boys preparing for overseas life, or even for farming in England.

One headmaster of a large London school writes: 'Parents are too timid in the matter of sending boys abroad. Boys admittedly fitted for overseas life are sent into some miserable parasitic and sedentary employment here. I shall be glad of light on the question of special curriculum for the practical boy.'

The following are also extracts from the replies received :—

'Mothers prefer to keep their boys under the family umbrella, and do not like them to emigrate.'

'Parents are the real obstacle—they may think imperially, but generally about other people's children.'

'Agriculture and horticulture are considered *infra dig.* because they are thought to be very slow roads to financial success.'

FARMERS' ATTITUDE.—It appears from the replies that the attitude of the farmer varies according to the neighbourhood. Generally it seems to be his wish that his boys should have a good broad general education. In some districts it is stated that he prefers that the time at school should not be spent on a subject such as agriculture, which he can teach himself, and for which the boy can get all the practical experience he needs at home during the holidays. On the other hand, experience at certain

schools in which agriculture plays an important part has shown that when the work is properly organised, and educationally directed, the farmers express themselves pleased at the provision made in the schools for dealing with agricultural principles and operations.

MANUAL INSTRUCTION.—Manual training, associated with the purely agricultural work, plays an important part in the preparation for farm life. It is evident that, in the absence of any facilities for actual work on the land, a boy can be encouraged to make himself useful by learning how to use tools both for wood and metal work.

It is not necessary to over-emphasise the vocational aspect of these occupations, since the educational value is equally great, but it is well known that boys take greater interest in doing things when they see and realise the usefulness of what they are learning. The educational value should be always present to the teacher, but it is the vocational aspect that appeals to boys, particularly to the type under consideration.

This truth is recognised by the majority of headmasters. Comparatively few schools have neither workshop nor laboratory, although unfortunately there are very few schools that provide instruction in metal as well as in wood work. For the boy who is likely to go overseas, a knowledge of forging, of machinery and of metal work generally is invaluable, 'but it largely depends even then upon the form which this instruction takes whether it will be useful or not for overseas requirements.'

Judging from the replies given to the question whether manual training formed a definite part of the school curriculum, or whether it was optional, and taken out-of-school hours, it is evident that manual training has not yet gained the recognition it should receive in our schools as an educational instrument. In far too many cases the manual work is optional and taken during out-of-school time. In a large number of those schools in which the subject forms part of the curriculum it is dropped at the age of fourteen, some headmasters believing that 'manual work can be learned better at an institution designed specifically for the purpose.'

In this connection the opinion as to the age at which manual work should begin was unanimously in favour of the earliest possible. For work on the land the age suggested was about twelve to thirteen for the horticultural work, fourteen and later for the agricultural work. In the case of more definite field work, many considered it should not be taken until after the General School Certificate Examination, *i.e.* not before sixteen years of age.

One headmaster writes: 'Get the interest in agricultural operations, &c., by creating the right atmosphere and surroundings as early as possible, but definite "instruction" must come after the boys have received a good general education. If boys receive "instruction" too early in agriculture, the subject comes to them stale.'

One or two headmasters suggested that boys who take agricultural work in place of a second foreign language should be allowed to offer that subject for the School Certificate Examination. One headmaster suggested that: 'Facilities for passing out from Sixth Form to farm training with local farmers, or agricultural colleges in preparation for going abroad, would be appreciated.'

VOCATIONAL OUTLOOK—NOT TRAINING.—Some replies indicate a misinterpretation of the statements contained in the prefatory note of the questionnaire. Some headmasters evidently supposed that it was a definite agricultural training that was being recommended, similar to that provided in an agricultural college for boys of eighteen and nineteen after leaving school. This is a complete misconception of the situation. It fails to realise the value of agricultural studies as an educational instrument, and it is misleading in its statement. It is the vocational *outlook* that is important, not the vocational training. The educational resources of land work when properly organised and co-ordinated with other parts of school work have been found to be very large. It is clearly recognised, and needs to be strongly emphasised, that school agricultural work cannot take the place of a definite apprenticeship on a farm, or of a more technical training at college. But it can, and does, give a boy an idea of what farming means, and a definite experience to guide him in deciding before it is too late whether he is fitted or not for the life of a farmer.

EFFECT ON CHARACTER, &c.—No. 7 of the questionnaire invited headmasters to express an opinion as to the effect that practical work on the land had on (*a*) a boy's attitude towards the general work of the school; (*b*) his character; (*c*) his interest and employment during out-of-school time.

In all those schools in which agricultural work has been organised as part of the curriculum, and in other schools where boys worked on allotments during the war,

or ran school gardens, the reports as to the effects on the character of the boys are wholly favourable. Expressions such as the following occur in replies from schools in Group A: 'Boys become more observant, more self-reliant,' 'independent,' 'improvement in health,' 'greater steadiness of character, no diminution of interest in school games, or work,' 'undoubtedly helped the general school work, and helped in developing character.' 'In every way results are satisfactory.' 'Many boys, of a certain type, who have stuck low in the school improve immensely in industry, character, and interest.' 'The scheme has had a most beneficial effect in every respect.'

'When taught by a master who is sound in both the practice and theory of agriculture, the subject can be the moral and educational salvation of many boys. (I have seen this on many occasions.) But the teacher must be master of the subject; for example, a science man who knows a little theory, and no practice, should not be allowed to teach it. I would emphasise two further points specially:—

'1. Observations of farm live stock during the course of natural events in the animal's life has a potent influence in purifying the minds of boys.

'2. Non-agricultural boys—probably the future town dwellers—obtain a wider outlook, and gather a wider sympathy with the problems of the land, and with those who work upon it, by daily contact with farm life.'

URBAN SCHOOLS.—In a large number of schools it is, of course, obviously impossible to give boys an opportunity of working on the land. Schools situated in large urban districts have no land in the immediate vicinity of the school available; but considered from the economic point of view the urban schools need the introduction of this broader outlook on life even more than the schools in the country. There the pressure of competition is greater. It should be possible to give the youths of our city schools some real insight into the open healthy life on the land, and the possibilities in the overseas Dominions of the British Empire, as offering an alternative to the sedentary life to which the ordinary school work generally leads. Methods of securing this were suggested in the following replies:—

'Manchester Grammar School has five Scout Troops and their work both in term and in the holidays is directly in line with the requirements of colonial pioneer life.

'Camping and trekking their best training; ten or more camp out every Whitsuntide and again in August and September.' 'A permanent camp in Cheshire in three army huts and outdoor work in nature study, geography, and astronomy.'

'Roan School, Greenwich, depends upon holiday courses; camping out on model farms a godsend to our town boys who long to go abroad and want some first-hand knowledge first.'

'Material for lectures on life in the Colonies might be sent to the schools, and the parents invited to attend.'

SCHOOL RESOURCES IN LAND.—It may be mentioned that nearly 50 per cent. of schools from which replies were received have access to land which could be used for agricultural and horticultural experiments, though only 9 per cent. of the schools are actually using the land for this purpose.

In many cases circumstances of staff, organisation, and funds are contributory difficulties. This is especially so in day schools, as travelling to and from school absorbs so much time. It is possible, however, to give boys an insight into farm life by means of lectures, and by adopting a science course which should include some of the problems connected with work on the land, such as the properties of the soil, climate, growth of plants, and animal physiology.

Only a few schools other than those in Group A can really claim that the science work is run with any agricultural bias. Some 30 per cent. of the replies show that botany, natural history, chemistry when taught in the schools are looked upon as providing a link with agriculture, but it is not at all clear that they do so in the sense meant by our questionnaire.

On the history side the value of good farming, and the part it has played in the economic life of the country, might be included in the syllabus, and thus contribute valuable aid in directing a boy's thoughts towards the land as the means of an honourable livelihood.

ATTITUDE OF HEADMASTERS.—The replies as a whole indicate that, while possibly a majority of headmasters are indifferent, non-committal, or definitely opposed to the suggestion of any practical work being undertaken by boys at school, a considerable number are very strongly in favour of the idea of a more practical outlook being given to a section at least of the boys concerned.

The following extracts represent some of the opinions expressed in the replies from schools in which no work of the kind indicated is attempted :—

'There is scope and usefulness in the idea of practical land training for a certain number of boys at an earlier age, and easier intellectual terms than are usually provided for admission to Reading and Wye, &c. But in all cases I feel very strongly that the age at which a start should be made for giving boys the opportunity of using their hands in manual work, or interested in agricultural or horticultural operations, should not be until (*a*) the literary training has reached the Oxford and Cambridge School Certificate standard, or (*b*) is despaired of, *i.e.* the age to be sixteen to eighteen.'

'Work of the agricultural type need not interfere with the general literary education up to fifteen or sixteen years of age.'

'Interested to hear of a practical scheme whereby this class of boys can be taught usefully at a public school up to the age of seventeen.'

II. GIRLS' SCHOOLS.

A modified form of the questionnaire issued to the boys' schools was sent to the headmistresses of 150 secondary schools for girls.

Replies were received from forty schools only, and a third of these indicate that little interest was taken in the subject.

The training in girls' schools for life overseas, *i.e.* a preparation for the ordinary activities likely to occur when living on a farm, would naturally take the shape of practical work in :—

(1) Domestic science—housecraft, cookery, needlework, laundry, with botany, chemistry, physics, and physiology more or less in relation to these vocational courses, as well as manual instruction in the use of simple tools, and in carpentry.

(2) School gardens—the cultivation of vegetables, and 'girl-guide' work.

These activities would provide a fairly comprehensive scheme for the purpose. Some were stated to form part of the curriculum in, at least, a third of the schools from which replies were received. These subjects were not adopted with a view to encourage emigration, but as part of the ordinary educational training.

Apparently little attempt is being made to interest girls in colonisation. It is considered that girls would not think of emigrating except for reasons of marriage, a contingency not likely to arise until some time after leaving school, and then unforeseen.

There is possibly not the same call from the vocational point of view as in the case of boys; but as a matter of fact the two cases are more closely related than appears on the surface. One of the drawbacks to sending our boys out to such lands as Australia is the dearth of marriageable girls there, and the almost prohibitive cost of a journey back to England to seek a wife when the young farmer wishes to settle down.

Several headmistresses report that every year there are a number of girls leaving school who would do better by adopting an overseas life on the land than by remaining in England. This suggests the need of a scheme whereby some of our surplus young women who have been educated in our secondary schools could be induced to go abroad to take part in farm activities such as milking, butter-making, chicken-rearing, &c., and through previous knowledge of practical life prove a more useful partner to a farmer.

In a number of schools some attempt is being made to provide a more practical curriculum, especially for those girls whose bent is not towards language and science.

The following schools may especially be mentioned: Bradford Girls' Grammar School; County School, Bishop Auckland; Christ's Hospital, Hertford; Croydon High School; Enfield County School; Guildford County School; Hitchin Grammar School; Horsham High School; Kentish Town County Secondary School; Kidderminster High School; Liverpool College; London Orphan School; St. Paul's School; Plumstead Secondary School; Salt High School, Shipley; Streatham County School; Twickenham County School; Blue School, Wells; Wigan High School.

Unfortunately, the pressure put upon the schools to push all pupils, whatever their different capacities, through rigid and altogether bookish external examinations without discrimination dominates the curriculum. The result is that no time can be spared for special subjects of the practical kind suggested above.

Some of the replies suggest that parents are opposed to such practical work, especially if the aim is preparation for overseas life. As in the case of boys, the

attitude of parents towards the subject of vocational interests varies according to the neighbourhood and school. In Yorkshire, for example, the parents consider it an essential part of a girl's education to become practical and efficient; while in Northampton, according to the experience of another headmistress, parents are loath to approve of school time being spent on other than academic subjects. In other schools, difficulties of finance, staff, and want of space are given as reasons against developments of this kind.

The Board of Education is blamed in other cases.

In quite a large number of schools the idea of giving girls manual work is treated as though it would demean them. One or two headmistresses refer to an objection on the part of the girls, not to the practical work in itself, but to the necessary curtailment of some of their book work in which they are making little or no progress. One headmistress calls the objection a kind of snobbery which makes girls regard the learning of French, &c., as a mark of superior social status.

This is, unfortunately, also true in boys' schools. Boys who would be, by common consent of the staff, much better employed for part of their time on the farm, forge, or other manual work in place of extra work in mathematics or language, object to joining the special class, as they are afraid of losing caste, the usual effect of a new subject. Parents frequently take the same line, sometimes even against the boy's or girl's own desire. A headmistress writes :—

'We established a housecraft course for just such girls in 1900, and it was successful up to 1914. Since the war, parents have preferred a course which would lead to earning a living, *e.g.* secretarial work, teaching, &c. Parents here expect their girls to remain at home ; they do not even like them taking work in other parts of England.'

On the other hand, in some girls' schools the introduction of wood work into the remove classes, or extension of practical work in housecraft for those evidently not profiting much from the more advanced literary or mathematical work, has had a stimulating effect on the girls' industry and self-respect. In many cases 'it has developed initiative, and the feeling that at any rate in something they are not duffers.'

Another headmistress writes : 'I have generally found that a girl who has practical ability gains confidence in herself, and so her standard in her general work improves, she develops a marked sense of responsibility, and follows up her practical pursuits as far as possible in her out-of-school time.'

Similar experiences of the effect on the less clever girl are forthcoming from the several schools, *e.g.* :—

'Has had excellent results in arousing interest.'

'The girls like the work ; there is no kind of intellectual snobbishness about it.'

The headmistress of a large London school writes : 'I look on gardening and hard work as of the greatest importance in giving many girls the chance of excelling who could not excel in book work.' 'Girls who are dull in ordinary lessons often develop well in the vocational course' is the testimony of another headmistress in London.

Usually where there is a laboratory the science work is arranged to form a basis for the domestic subjects, chemistry and physics for cookery, animal physiology for hygiene, &c.

It is evident that such practical work has quickened interest in both in-school and out-of-school occupations, but there is no school apparently where such work involves the intentional purpose of preparing girls for life overseas.

III. BOARD OF EDUCATION AND COUNTY COMMITTEES.

BOARD OF EDUCATION.—Inquiries at the Board of Education only elicited the fact the Board had no information to offer beyond a knowledge that one or two well-known schools were interested in the subject and in these attention was paid to the needs of boys who intended to emigrate.

COUNTY AUTHORITIES.—Twenty County Authorities for Higher Education were written to. Ten replied, and of these only six appeared at all interested ; the subject being from their point of view a concern of individual schools rather than that of the administrative body.

Wood work and manual instruction generally are encouraged in the County Secondary Schools as part of the regular curriculum by the authorities for Berkshire, Gloucestershire, Middlesex, Staffordshire, Warwickshire, West Riding of Yorkshire.

The Director of Education for Warwickshire writes : 'It is practically impossible at the great majority of schools to give anything in the nature of a practical agricultural training. Except at the larger schools there would not be sufficient number of boys to enable a special class to be formed. Also it would mean the engagement of special teachers, and that the great majority of such schools are too hard hit financially to contemplate this extra expense. Little is possible in this direction unless the secondary schools receive much larger grants from the Government.'

The Director for West Riding points out that local industries absorb the attention of boys with a practical bias; he refers to the Knaresborough Rural Secondary School as the only school in the district with an agricultural bias. He states that 'the school has been an undoubted success, but that there has not been a sufficient demand for education of this type to lead my committee to establish another school on similar lines.'

The West Riding Council offer Agricultural Exhibitions tenable at Leeds University and at the County Farm, Garforth. These exhibitions provide for free tuition at the University and at the Farm. In addition, the Council contribute 25*s.* per week during the session as an allowance towards maintenance and travelling expenses. Exhibitions are also provided for dairy courses at the County Farm.

The Secretary of the Berkshire Education Committee writes as follows : 'Until 1913 my committee dealt with agricultural education as part of secondary education, but since that date agriculture had been in the hands of two other committees. Under the working agreement between the Board of Education and the Ministry of Agriculture, the Education Committee still deal with instruction of an agricultural or technical kind given to students under sixteen in schools or in evening classes.

'During the last twenty years we have made many efforts to arouse interest in this subject, but experience has shown that, except in the case of school gardens, there is no constant demand for systematic training. Scholarships were offered year after year without attracting a single suitable applicant, more often no candidates at all. I understand that the Agricultural Instruction Committee find that this difficulty continues. Efforts to give an agricultural bias to the curriculum of our secondary schools (seven are maintained secondary schools out of eleven) have not been successful as a whole.

'The curriculum of these schools is, as a rule, sufficiently varied to admit of both boys and girls getting a fair amount of practical instruction but without any direct connection with farm work.

'As regards the county itself, the profits to be made in farming were not sufficient to encourage students to take up courses either in schools or colleges, and we have found that farmers' sons, as a rule, have been sent to boarding schools rather than to secondary day schools. The same is true of the daughters, who, however, on returning home, have in many cases been willing to take up classes in dairying and poultry management, but did not often go further, except in the case of horticulture.'

Canon Sewell, Chairman of the Gloucester Higher Education Sub-Committee, writes : 'My committee, ever since 1903, have taken a great interest in what has been called "practical education." Gloucestershire has done more than most rural counties to provide opportunities for boys and girls in the elementary schools to make things and do things. They have for many years made a point of providing workshops, usually for woodwork but sometimes for ironwork also, in connection with new schools and where possible old ones too, in which boys can familiarise themselves with the use of tools and design and make and mend things useful in the garden, on the farm and in the home. They have also developed school gardening and the care of poultry and other live stock, and I enclose copies of recent reports which record their experience.

'Domestic Science Centres are provided wherever possible for the girls.

'While this kind of teaching has its vocational uses, its educational value more than justifies it. It is undoubtedly true, as you suggest, that it has a beneficial effect upon the character of the individual and leads to a clearer understanding of, and a happier attitude towards, the other studies. As soon as they are seen to have a practical value they are pursued in quite a different spirit.

'While it has not yet been possible to give this practical bias to the work of the secondary schools, the desirability of doing it has never been lost sight of. Headmasters and governing bodies have been approached on the subject and it has been suggested that in rural schools science should be taught with an eye to the farm.

'At present time the committee have under consideration the provision of a

secondary school in Northleach, which is the centre of a thinly populated area with no industry but agriculture, and it is hoped that when the school is built it will be furnished with workshops where, after courses in wood and iron work, the boys may learn something about heat engines and the application of electric power.

'It is believed that the sons of farmers and agricultural workers would find this kind of instruction very useful to them here in Gloucestershire, and it would at the same time do much to equip them for life in one of the overseas Dominions and no doubt to turn their minds to it.'

IV. OVERSEAS DOMINIONS.

Inquiries have been made of the various High Commissioners or Agents-General of the overseas Dominions for any reports, or publications, dealing with the question of curriculum of their schools educating boys and girls who are likely to find occupations on farms, and in other rural occupations. They were further asked to express any known views held by those most interested in the matter, viz. the probable employers of immigrants, and those responsible for the general welfare of the community.

CANADA.—A special committee appointed by the Minister of Education for Ontario, consisting of representatives of University Colleges, High Schools, Inspectors, and the Department of Education, recommended very drastic alterations in the curriculum and public examinations of the high or secondary schools. Many of these recommendations have been adopted, and were in force in 1922. The inclusion of agriculture as an optional subject in place of physics and chemistry is one interesting feature of the new order.

'This is an entirely new departure,' writes the Inspector of High Schools, in his annual report of 1921. 'It is a recognition of the value of the study of agriculture as a means of mental training as well as of its practical value in Ontario, where agriculture is still the basic industry.'

A four years' course of instruction in agriculture has been drawn up for the high schools of Ontario, and any student is given credit for this work if he desires it for entrance to the University, the Normal College, or the Ontario Agricultural College.

The chief difficulty in carrying out the scheme has been lack of qualified teachers, but it is anticipated that this will be a rapidly diminishing difficulty as the work develops in the high schools. In 1900, 1,322 pupils took up agriculture on leaving school, as against 3,142 who went into commerce.

Agriculture has also been introduced into the public or elementary schools of Ontario, with very promising results. The Inspector of this work writes: 'The introduction of classes in agriculture into the rural schools has already produced tangible results in a direction not at first expected. Through the use of school gardens as a part of the work of the school the interest of both pupils and parents has been awakened towards the improvement of the school grounds and buildings, and this aspect of education is having a particularly far-reaching effect and is no less important than the scholastic type.' This work is aided by special grants from the Government. In 1920 the grant was £15,000, in 1921 it was £16,000.

NEW ZEALAND.—In New Zealand, according to the report of the Minister of Education, in addition to an academic course, secondary schools generally provide courses with a commercial, agricultural, or a domestic bias.

In the district high schools the courses are still more of a nature directly bearing upon the vocation shortly to be followed by the pupils, many of the schools providing a full rural course of instruction. The result is, agricultural science is taken by 71 per cent. of the boys and 23 per cent. of the girls, wood and metal work by 62 per cent. of the boys, needlework and cookery by 64 per cent. of the girls, in place of the more academic course.

A letter received from the Director of Education for New Zealand further explains the situation :—

'It is, of course, not possible for the Department to treat in any detailed or definite manner the broad issues raised by you as to the type of education suitable for boys and girls who are likely to seek a home in the Colonies. In general terms, it may be stated that the educational training appropriate for rural life in New Zealand is similar to that required for English rural life. While there are necessarily many points of difference between conditions in the respective countries, it is safe to affirm that these are more than balanced by the points of resemblance.

'The comparatively newly-settled state of this country brings its own special problems; but the distinction between the two countries in this respect is apt to be exaggerated rather than under-estimated. The predominant type of farming in New Zealand is dairying, and the typical holding is not large in area. Thus, of the holdings of more than ten acres, well over 50 per cent. comprise less than 200 acres, while less than 10 per cent. exceed 1,000 acres. There is a well-defined tendency towards closer settlement, and here, as in most agricultural countries, future progress undoubtedly depends upon the success with which intensive methods of cultivation are applied to relatively limited areas of land. The problems which to an increasing extent demand attention are the application of scientific processes to agriculture, the more extensive use of labour-saving machinery, and the devising of economical methods of transport and marketing. These problems are, of course, by no means peculiar to New Zealand, and your inquiry may, as suggested, be answered in general terms as above.

'The express limitation of the field of your inquiry to secondary schools makes one hesitate to suggest courses of instruction which will more fittingly find a place in the curriculum of schools of other and more specialised types. The following subjects are mentioned as indicating directions in which, to a greater or less degree, it might be possible to bring education into closer touch with the problems confronting settlers in this country. A number of references are given to publications which show in some detail the course of instruction attempted in the respective subjects:

'*Agriculture*: The syllabus prescribed for the Matriculation Examination and University Entrance Scholarships (New Zealand University Calendar, pages 16 and 37), and for the Public Service Entrance Examination (Pamphlet N.4, page 13), fairly describe the work undertaken by advanced pupils. At pages 56-61 of the Pamphlet N.8 will be found a description of the subject, Nature Study, as taught in our public schools; while these are elementary schools, it may be noted that in general they provide education for children up to the age of about fourteen years, or some two years in advance of the English elementary schools.

'*Woodwork, Metalwork*, and related subjects are defined at pages 21-24 of the Pamphlet N.9. The University Calendar (page 170, *et seq.*) sets out similar subjects of an advanced nature. These are for the most part beyond the reasonable requirements of a secondary school, but the courses there prescribed for the degrees of Bachelor of Engineering and of Agriculture will in some measure illustrate the adaptation to New Zealand conditions of the subjects prescribed.

'*Arithmetic and Book-keeping*: It is evident that these subjects, both of them essential to the farmer, can well be given a bent in the direction of touching rural problems rather than the somewhat restricted field of commercial operations to which they are commonly confined.

'*Home Science*: In view of the general recognition already given to this subject, it is scarcely necessary to stress its importance beyond stating that the arguments favouring its inclusion in girls' education apply with special force in the case of the persons for whose benefit your inquiry has been undertaken.'

AUSTRALIA.—The Director of Education for New South Wales writes that the type of education best suited for boys for overseas life are those provided by our Rural and Junior Technical Schools. The courses of education provided at these schools are briefly described hereunder, and the Director says: 'I am confident that if these courses are introduced into England, they will provide the boy who intends later on to seek his fortune in this land with the basis of an education that will be considerably helpful to him in either the rural or industrial life of the State.'

The Rural Course of Instruction is specially designed for boys and girls associated with rural life, the aim being to impart to the pupils a manual and scientific training which will be decidedly helpful in enabling them to grapple with the economic and social problems which are inseparable from our present-day rural and agricultural vocations.

The course extends over a period of three years, and the instruction, which is super-primary in nature, is given to those pupils who have completed the ordinary course prescribed for the primary school. The subjects taught include elementary agriculture, agricultural nature study, applied farm mechanics (carpentry, blacksmithing, plumbing) and rural economics for boys. The girls attending the schools are provided with a complete course in domestic science and horticulture.

The course at the Junior Technical Schools extends over a period of three years, emphasis being given to general subjects with the anticipation that, at the end of

three years, the boys will be able to reach the standard of the Intermediate Certificate Examination. The manual work is given less emphasis during the first year.

The examination held at the end of three years' course comprises English and mathematics, elementary science, woodwork, metalwork, and geometrical drawing. English and mathematics are emphasised throughout the course, so that a high standard of general education may be assured.

V. OVERSEAS SETTLEMENT COMMITTEE AND KINDRED ORGANISATIONS.

Inquiries were made of the following bodies for information respecting their experience as to the kind of educational training in secondary schools for boys and girls likely to go overseas: (1) Oversea Settlement Office; (2) Oversea Settlement of British Women; (3) Victoria League; (4) League of the Empire; (5) Public Schools Employment Bureau (Overseas Section); (6) Universities Bureau of the British Empire: (7) Parents' National Educational Union.

Sympathetic replies were received from most of these organisations, but they have naturally been formed for dealing with the school product rather than with the method of producing.

The Public School Bureau, while emphasising the desirability that a boy who has definitely decided to devote his life to agriculture overseas should begin with a short preliminary course in England for the purpose of testing his fitness, overlooks the obvious fact that if he is not fitted for such life, this course entails so much more delay in his start in life, a delay which need not occur if the school provided some opportunity of work on the land.

The Oversea Settlement Committee state they are anxious to stimulate the migration of boys and girls from public and secondary schools, and every possible avenue for providing suitable openings overseas is being explored, that 'they have always regarded it as desirable that the education afforded in this country should be of such a kind as to impart the fullest possible knowledge of conditions overseas, and should fit suitable members of the rising generation for life in other parts of the Empire.' Further, that as 'the main openings overseas are for land workers, it seems desirable that everything possible should be done to stimulate the interest of boys in farm work and farm pursuits. The settlement overseas of young women and girls is at least as important and certainly no less difficult a branch of this problem.'

The Secretary for the Overseas Settlement of British Women writes: 'The whole question of training is receiving consideration at the present time, and our view is that the primary training required is in connection with household economy. Under this head, teaching in dairying and horticulture would be embraced, but not the larger branches of agriculture. There are signs that the scholastic authorities and others are beginning to understand the necessity for more fundamental and plain teaching, and it is hoped that further developments will be along these lines.'

CONCLUSIONS.

1. A demand exists on the part of the overseas Dominions for boys of the right type with an agricultural bias, if not with training, and coincides with the home country's need of finding healthy employment within the Empire for a large number of her sons.

2. The public schools and other large secondary schools of Great Britain send into the world every year a considerable number of boys of the right type who love wide open spaces, and dislike intensely the overcrowded city life.

3. There has been no serious attempt in the majority of schools to meet this demand. Schools hitherto have provided only three avenues—literary, mathematical, and scientific—in some places only two. While this is sufficient for many boys, it does not provide for the most practical type, so that numbers find no outlet for their natural ability in that spirit of enterprise and adventure which Dominion life offers. They lack necessary guidance and experience.

4. The undoubted value of agriculture as an educational instrument has been overlooked in the past. Some British schools have made the experiment of adding this new method for educating boys of the latter type. A school farm or science farm has been set up in the working of which boys take an active part. This farm provides material for working in other subjects, such as mathematics and general

science, it encourages reading for a definite purpose, the observation of natural phenomena, the keeping of records, and adds considerably to the appreciation of geography. Thus the school farm, when properly used, is a valuable means of education and appeals to boys on whom the older classical and mathematical methods make no impression.

5. Experience shows that the school curriculum does form an important influence in deciding a boy's career. The school farm would, therefore, bring to the notice of boys the possibilities of a career on the land. It would give them sufficient experience of what agriculture means, and so enable them to decide whether they are fitted or not for such a life.

6. The extension of the experiment to other schools is not prevented by lack of land in many cases; 50 per cent. of the schools have access to suitable land, but only 9 per cent. use it.

7. Development of a school curriculum in this practical direction for a section of a school needs encouragement because: (*a*) it is educational in a very wide sense; (*b*) Empire considerations demand it; (*c*) little is being done officially either by the Board of Education or by the majority of Local Examination Authorities.

8. There is need of some organisation to encourage overseas life, to link up the secondary schools with those societies which are able to look after the interests of the prospective emigrant.

9. Whatever agricultural training a boy may receive at school, it should be clearly emphasised that the training is not technical such as is given in an agricultural college, and that it can be in no sense a substitute for a definite apprenticeship on a farm, whether in Great Britain or in one of the overseas Dominions.

10. Manual training as an educational instrument does not appear to receive the recognition it should in the majority of schools. Comparatively few have facilities for metalwork, and in the majority even woodwork is optional and taken during out-of-school time, or, at most, in the lower forms only.

Extracts from letter received in reply to questionnaire from headmaster of Abbotsholme School, Derbyshire.

'At Abbotsholme, Derbyshire, the general scheme of education is compulsory for all, whether they are going to the Colonies or not. It is thought that any boy studying the natural sciences is all the better for having contact with actual life out-of-doors, contact with the soil; some knowledge of the general methods of food production is considered here necessary for all educated people in order to remedy the one-sidedness of mere class-room instruction.

'Boys are largely influenced during the adolescent period particularly by what they see going on around.

'The effect of practical work on the land or in the workshop on the character of the boy and his attitude to his other studies has been in my experience a very great help in every way. Practical work of all kinds brings the boy in contact with the realities of life, and, when he comes into the class-room, he finds the teaching there throws light on the solution of the problems suggested by his practical occupation in workshop or out-of-doors.

'Every boy prefers to have active work with tools to sitting indoors over books; to do practical work, especially out-of-doors, is one of the best means of relieving the adolescent tension, which is seriously accentuated by the usual excessive sitting indoors. Consequently, practical studies have an enormous moral value.

'Lads brought up on a farm have a much more wholesome view about sex questions, and have none of that sort of shame-faced curiosity and uncleanness of mind which is engendered by the artificial town life. The latter admits of no access to the simple, natural matters of daily occurrence on a farm.

'Few boys have the courage to do in England what they would have to do overseas, owing to the snobbery which worships a type of person who is called "cultured," and who dawdles about, amusing himself or herself, while living largely on incomes from investments in all manner of industrial concerns, as well as in Government Stocks, &c. There is something extraordinarily attractive in the open-air practical life in the Dominions and United States, where everybody is respected, if he is doing actual work, and everybody is despised who does nothing but pass his life living on the proceeds of investments.'

ADDENDUM.

Questionnaire.

The following was the scope of the questionnaire, the paragraphs or words in italics representing the chief differences in the form issued to girls' schools.

1. Has the question of any special training suggested by the above preamble, and the possibility of its being introduced into the educational scheme of the school, been considered : (*a*) if so, what is the nature of the provision made ? (*b*) if not, what are the possibilities of such being introduced in the near future, or what reasons would prevent such development ?

2. Has there been at any time any expressed desire on the part of the boys (*girls*) or their parents for such training ?

3. Do many boys (*girls*), or any, leave each year who, in your opinion, would have done better if they had adopted an overseas life on the land than by remaining in England ?

4. What facilities exist in the school for manual work suitable as a preparation for the ordinary activities likely to occur in working on the land ?

5. Is such manual training a definite part of the school curriculum, or is it optional and taken only in out-of-school hours, instead of games ?

6. If adopted in any shape, at what age would you consider a start should be made in giving boys (*girls*) the opportunity of using their hands in manual work, or of becoming interested in agricultural or horticultural (*household*) operations ?

7. If any scheme has been adopted at your school to arouse interest, as sketched above, in out-of-door pursuits, what impressions have you gained as to its effect (*a*) on the boy's attitude towards the general work in the school, (*b*) on his character, (*c*) on his interest and employment during out-of-school time ? Are many of the boys so interested ?

If any scheme has been adopted at your school to arouse a girl's interest in such pursuits, what impressions have you gained as to its effect on her attitude towards the general work in the school, on her character, and how far does such interest extend into out-of-school time ?

8. Where no opportunity exists of boys working on the land while at school owing to its situation, has any of the science work in the laboratories any practical agricultural or rural industrial bias, *e.g.* problems that concern the properties of the soil, the growth of plants, and animal physiology ?

Where no opportunity exists of girls working in the house or outside while at school owing to its organisation, has any of the science work in the laboratories any practical application, e.g. *problems that concern the properties of household articles, the kinds of foods, and animal physiology ?*

9. Has the school access to any land of which it could make use for the purpose of educational work, or if not, is there any prospect, or possibility, of such being acquired ?

10. In the absence of any direct agricultural work at school, to what extent, if any, has the school sent boys to 'training' farms for overseas life, either in England or in the Colonies ?

Has any special attempt been made to interest the girls in colonisation as a career, e.g. *by the interchange of their staff with those from the Colonies ?*

11. General remarks or suggestions.

Is there any attempt to link up old girls who have already gone to the Colonies with younger girls who may be desirous of emigrating themselves ?

SECTIONAL TRANSACTIONS.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 464.)

Thursday, August 7.

1. Prof. A. Fowler, F.R.S.—*The Spectra of Ionised Elements.*

The paper gives a summary of recent work on the spectra of ionised and multiple-ionised atoms. In the case of silicon, four successive spectra have been sufficiently observed to permit the complete or partial classification of the lines in series. In passing from Si IV to Si I, the effects of adding external electrons one by one are exhibited under somewhat simpler conditions than in the regular sequence of the neutral atoms of Na, Mg, Al, and Si, since the charge and the mass of the nucleus remain constant. Similar changes in the spectra of other elements have been observed, and series have been worked out for C II. The ionisation potentials deduced from the series of silicon and carbon have an important application in connection with the determination of the temperatures and densities of stellar atmospheres.

2. Dr. F. L. Mohler and Dr. P. D. Foote.—*Critical Potentials and their Interpretation.*

Available data on the normal energy levels of atoms, particularly in the range inaccessible to spectroscopic methods, are summarised. Results obtained in this laboratory on radiation potentials of gases and stages in the excitation of spectra are compared with critical radiation potentials of solids and other data on soft X-ray limits. Moseley diagrams of these limits give curves of the type predicted by Bohr.

Some questions as to the interpretation of critical potentials can be settled on the basis of this correlation of results.

3. Prof. J. C. McLennan, F.R.S.—*Recent Studies in Band Spectra and their Bearing on the Structure of Molecules.*

4. Mr. R. H. Fowler.—*Mechanisms of Excitation, Ionisation, and Dissociation in Statistical Theory.*

This paper attempts a systematising survey of current theory and experimental evidence about the processes occurring, or mechanisms of exchange normally acting, in gaseous assemblies, particularly at high temperatures. Two different hypotheses form possible starting-points : (A) *The hypothesis of preservation*, that the actual distribution laws for the systems in any assembly in equilibrium must be the same whatever the mechanisms of exchange that are setting up this equilibrium; (B) *The hypothesis of detailed balancing*, that in equilibrium the effects of any specified process, or element of a process, must be balanced exactly by another which is the exact reverse of the one specified, differing, that is, only in a reversed time scale. These hypotheses are not equivalent, (B) being more restrictive than (A), and a number of mechanisms are re-examined explicitly in the light of these hypotheses, including the mechanism of excitation by collision (Klein and Rosseland), ionisation and dissociation by collision (Becker), excitation by radiation (Einstein), scattering by free electrons (Einstein and Ehrenfest), and the photo-electric effect (Kramers, Milne).

5. Dr. R. J. Piersol.—*Pulling Electrons from Metals by Intense Electric Fields.*

The tube contains electrodes made from molybdenum plates pressed into hemispherical shells, welded to tungsten rods which are sealed into a hard glass tube. The discharge gap is 0.023 cm. A charcoal bulb is attached which is kept at 386° C. The electrodes are heated to 1,400° C. by induction furnace, the tube is baked at 500° C., the vacuation covering forty-eight hours. The connected tube and bulb is sealed off. The bulb is placed in liquid air and the discharge tube is heated at 500° C. for two hours. Then the tube is slowly sealed off from the charcoal bulb. The critical gradient is 5,400 Kv/cm. This minimum potential is sharply defined, showing that proper outgassing completely eliminates field currents, thereby giving a definite gradient of cold electronic discharge.

6. Dr. Ann C. Davies.—*The Metastability of the Fundamental Coplanar Condition of the Helium Atom.*

Further experimental evidence bearing on the conclusions of Horton and Davies that an emission of radiation results from the displacement of an electron within a helium atom from the normal orbit (the fundamental orbit of the crossed system) to the first outer orbit (the fundamental orbit of the coplanar system), and that this radiation can be absorbed by normal helium atoms, these conclusions being at variance with the conception of the fundamental coplanar condition of the helium atom as a metastable state.

7. Prof. H. N. Russell.—*The Spectrum of Titanium.*

8. Prof. Frank Allen.—*Visual Sensory Reflexes.*

In endeavouring to discover the fundamental processes of colour vision, experiments were conducted by fatiguing the left eye with a series of monochromatic spectral colours and making measurements of the effects produced on the right eye. The method used was the measurement of the critical frequency of flicker. In these experiments the dark room was discarded and the eye was maintained in ordinary daylight adaptation. The results showed the existence of visual sensory reflexes, the chief effect of which is to enhance the sensitiveness of the receptors of all three fundamental colour sensations in the right eye.

In a similar manner the right eye was fatigued, and it was found that both direct and reflex effects were simultaneously produced. The simple colours—red, green and violet—affect one sensation directly and two reflexly. The compound colours—orange, yellow and blue—affect two sensations directly and one reflexly. No doubt all colours affect all three sensations both directly and reflexly, but the experiments give the net final results.

Similar experiments were tried by confining fatigue to one side of a retina and measuring the reflex effects produced on the other side. They were precisely the same as in the binocular experiments.

The reflex principle seems to give an adequate explanation of a monocular and binocular contrast, positive and negative after-images, and the general phenomena of colour vision.

The results strongly confirm the three-components theory of Thomas Young.

9. Mr. F. J. W. Whipple.—*An Experiment Illustrating the Theory of the Green Flash.*

When the sun sets under favourable conditions the last glimpse appears a brilliant green.

The theory that the phenomenon is due to the simultaneous action of dispersion and absorption is now generally accepted. The experiment is designed to illustrate this theory.

10. Sir Richard Paget, Bart.—*The Nature and Artificial Production of Speech Sounds.*

The resonances heard in the lecturer's own whispered vowel sounds were compared with those obtained by instrumental methods by Dr. D. C. Miller (' Science of Musical Sounds,' 1916, Lecture VII, page 235 *et seq.*).

The double resonances obtained by Miller for the vowel sounds mat, met, mate, meet, were shown to be comparable with the lecturer's own resonances æ (hat), e (men), ei (hay), and ī (eat), allowing for variation of pitch due to differences of pronunciation.

For the vowel sounds ma, maw, mow, moo, for which Miller finds only a single resonance, observations by ear showed double resonances, one resonance of which in each case was fairly comparable with Miller's single resonance.

It was demonstrated that the English vowel sounds ɑ (calm), e (men), ī (eat), ɔ (all), u (who), could be recognisably reproduced by means of an organ reed attached to a single cylindrical resonator of cardboard divided into two resonators of proper pitch by means of a central perforated diaphragm or stop, the actual resonances being ɑ, 1084/683 ; e, 1722/406 ; ī, 2298/342 ; ɔ, 861/483 ; u, 812/322. The cardboard resonator gave similar vowel sounds to those of plasticene metal or glass.

The same organ reed was attached in succession to two single resonators tuned respectively to Miller's whispered frequencies 781 (ɔ) and 383 (u).

It was shown that though there was a trace of the ɔ sound in the case of a single resonator of 781, there was no trace of u sound in the case of a single resonator of 383.

Reference was also made to the recent work of Crandall and Sacia (*Bell System Telephone Journal*, April 1924, vol. 3, No. 2, pp. 232-7). These results of vowel sound analysis made by a system of electrical filters showed clear double resonances for the vowel sounds ɑ, ɒ (not), ou (no), u, ʊ (put), the vowel sound ɔ (all) being shown as having a single extended region of resonance coinciding with that of the two separate resonances heard in the lecturer's voice.

Crandall and Sacia found certain additional resonances. It was suggested that some of these might be distinctive of the American accent. In the lecturer's own voice, when producing the vowel sound æ (hat) with the American accent, an additional resonance of the order of 2,700 was audible. This resonance appeared to be due to a constriction of the pharynx, as though the back resonator were divided into two resonating cavities.

The experiment was shown of constricting a rubber tube model. It appeared that by constriction of the rear portion of the back resonator an appreciable ' nasal ' quality was added to the vowel sound.

Experiment was shown of slowing down the speed of a dictaphone record of the vowel sound ʌ (as in up) which gave in succession sounds very similar to ɑ (calm), ɒ (not), ɔ (all), and u (who) by successive reduction of the speed of the driving mechanism.

A sound similar to ʊ (put) was also produced by slowing down a record of the vowel sound æ (hat).

The cumulative effect of these experiments appeared to indicate that the vowel sounds ɑ (calm), ɒ (not), ɔ (all), u (who) and ʊ (put) were all in effect due to double resonance.

The artificial production of consonants by means of resonators was shown, consonants m and n being reproduced by a double resonator of frequency 2169/342 giving the vowel sound ɪ (it) and having a third (nasal) resonator of frequency 704 connected to the back resonator. With this model, closure and release of the mouth during blowing produced mi : closure and release of the central orifice gave ni. The two operations in succession produced the name ' Minnie.'

The production of the consonants p, t, k, v, z, dh, r (untrilled) and r (guttural) was shown by means of a flexible double resonator made of a 1-in. diameter rubber tube actuated by an air-blown reed. It was shown that the different consonants were produced by the varying resonance effects of complete or partial closure and release at different points in the length of the tube. The untrilled r sound was shown to be due to a double restriction.

The consonant sound ' l ' was proved to be due to a rapid change of resonance, the ' l ' sound being lost if the same changes were made at a slow speed.

The general conclusion was that the consonant sounds are as essentially musical as the vowels, and are produced in a similar manner, viz.—by resonance. The principal differences were that, whereas the vowel sounds represent the effect of

different postures of the vocal organs, most of the consonants represent the effect of different gestures or movements by which the successive vowel postures are reached. The consonants were in general produced by resonators of smaller orifice than the vowels, in many cases by more than two resonators, and in many cases by resonances which changed in a characteristic way in pitch or amplitude or both. In general the human ear identifies the characteristic gestures by means of the audible resonance changes which they produce.

11. Prof. P. E. Sabine.—*Research in Architectural Acoustics.*

A brief summary of the Reverberation or Sound Chamber method of acoustical measurements is presented. This method makes use of the fact that sound from a source within a closed space remains audible for an easily measurable length of time after the source has ceased. This time, T, will depend upon E, the acoustical power of the source, t, the time during which it speaks, V, the volume of air in the room, A, the rate of dissipation of sound energy, and i, the minimum audible sound energy density. Assuming that the time during which the source speaks has been sufficiently great for the density of sound energy in the room to reach the steady state I_0, in which the sound produced per second equals the sound dissipated per second, the time required for the density to fall to the threshold density i is given by the relation

$$\text{(1)} \qquad AT = \log\left(\frac{E}{VAi}\right).$$

A is defined by the equation

$$\text{(2)} \qquad \frac{dI}{dt} = -AI.$$

A, for sound of any pitch within a given room, is determined initially by varying the acoustical power of the source of sound in known ratios and measuring the duration of audibility of the residual sound after the source has ceased. A is the slope of the straight line obtained by plotting log E as a function of T. Knowing A, the ratio $\frac{E}{i}$ for any observer follows from Equation (1).

The arrangement of the Sound Chamber in the Wallace Clement Sabine Laboratory at Riverbank, Geneva, Illinois, is described. Illustrating the use of such a room, the method and results of a quantitative study of non-musical impact sounds, such as the noise from the operation of typewriters and the like, are given.

The results of a research programme on the general problem of the reduction of sound transmitted by partition walls are summarised. This research has included measurements on so-called sound ' deadening quilts ' ; that is, materials which are porous and inelastically compressible and flexible, structural units of wood, glass and steel of various types, and standard masonry partitions of different materials.

The experiments show that reduction of sound in transmission by homogeneous felts and the like is a true absorption process, so that I, the density of sound energy on the further side of a thickness x of a material of this sort, is given by the expression

$$I = \frac{I_0}{r} e^{-qx}.$$

Thus the sound-insulating value of a material of this character may be specified by the two experimentally determined coefficients r and q.

In masonry walls the resonance of the structure as a whole and in segments is an important factor in sound transmission, so that experiments with a single tone are difficult to interpret. Extending the investigation to the whole scale of tones, experiments on some fifteen different masonry walls of different materials and thicknesses show that the general reduction of sound in transmission through such walls is independent of the material and the structural stiffness of the wall, and is a function only of the weight per unit area.

Friday, August 8.

12. Sir Napier Shaw, F.R.S.—*If the Earth went Dry.*

The phenomena of the general circulation of the atmosphere depend fundamentally upon warming at the surface by the sun's rays and on cooling these by outward radiation; but the dominant factor of weather is the modification due to water-vapour in the air. In this paper, in order to clear ideas, the reader is invited to regard these two aspects of thermal influence as distinct, and to consider the effect of 'dry heat' alone. We thus form an idea of what the general circulation would be if there were no water-vapour at all in the air.

The subject is hypothetical, inasmuch as the actual circulation is generally affected by the condensation or evaporation of water, but its discussion is not necessarily sterile. It is an exercise in some important points of thermal economy; in deserts the conditions postulated are approximately realised, and yet winds, dust-storms, and 'dust devils' are not infrequent there; and in the large part of the atmosphere where the temperature is below 270 t the relative amount of water-vapour, though not by any means without function, is too small to play the dominant rôle.

It is assumed that 'dry' air (except for dust) would be perfectly transparent. Radiation received by a perfect absorber normal to the sun's rays would be 135 kilowatts per square dekametre (subject to small variations of the solar constant), and the loss of heat from a surface radiating perfectly (subject to local variation on account of dust) would be $.572 \times (t/100)^4$ kw., and range from 9 kilowatts per $(10 \text{ metre})^2$ for 200 t to 46 for 300 t. A table is given of the temperatures (between 200 t and 402 t) at which the loss from a radiating surface would balance the income for given solar altitudes.

The technical discussion is in five sections :—

1. A survey of the thermal processes operative in the absence of water-vapour : (*a*) the katabatic effect of inclined surfaces cooling in the polar night; (*b*) the slow thermal convection, upward, by the building up of layers of dry air in convective equilibrium over flat solarised surfaces (incidentally the question of superheated air is dealt with); and (*c*) the mixing of superposed layers by eddy-motion.

2. An estimate of the flow of air necessary to keep a steady state of temperature on a polar slope under assumed conditions during prolonged nocturnal radiation. A possible value of 300 km. per hour offers a justification for the use of the term 'dust blizzard' as descriptive of the weather.

3. An estimate of 2 km. as the probable daily height of a layer in convective equilibrium under a tropical sun.

4. Diagrammatic sections of surfaces of equal temperature and of equal potential temperature for sunrise and sunset at solstice and equinox. A permanent stratosphere, nibbled daily by a convective troposphere, is presupposed for the purpose of estimating its probable temperature, which is near 300 t. The incidental curiosities of temperature are set out.

5. The pressure and winds consequent upon the temperature are sketched, with the conclusion that a polar front would still be operative and a general circulation not dissimilar in some of its main features from the present form.

13. Sir Frederic Stupart.—*The Variableness of Canadian Winters.*

In normal seasons North Pacific cyclonic areas usually move south-eastward, with their centres well off the coast until at about the latitude of Northern British Columbia they enter the continent, while anticyclonic conditions of moderate intensity with low temperature prevail in Yukon and the Mackenzie River.

In certain years, however, the Pacific cyclonic areas are less intense and enter the continent further south, while great anticyclonic developments occur in the far north and sweep south-eastward over Canada, accompanied by severe cold waves, which not infrequently reach the Atlantic coast. These conditions lead to abnormally cold winters in Canada.

In other years the North Pacific cyclonic areas appear to be of such intensity

that they force their way into the continent in high latitudes and actually prevent the formation of anticyclones and their concomitant low temperature. These conditions lead to mild winters in Canada.

The Meteorological Service is investigating as to whether there is any connection between the temperature and position of the Japan current and the behaviour of these cyclonic areas.

14. Prof. A. H. Compton.—*The Quantum Theory of the Scattering of X-rays.*

15. Prof. J. A. Gray.—*Scattering of X- and Gamma-rays and the Production of Tertiary X-rays.*

1. Experiments with X-rays show that the proportion of scattered rays of longer wave-length than the primary is independent of the crystalline structure and thickness of the radiator.
2. The rather peculiar intensity distribution curves of unmodified and modified scattered radiations suggest that they are not really independent types.
3. Results on the scattering of γ-rays do not altogether agree with the quantum theory of scattering.
4. The 'tertiary' X-rays discovered by Clark and Duane must be formed in the atoms in which the photoelectrons are produced. They may even be a special type of scattered rays.
5. If X-rays consist of quanta, they should have a range. [If this is the case, in the writer's opinion the wave theory should be abandoned.]
6. The writer, while aware of the difficulty of explaining certain results by the wave theory, believes that other results cannot be explained without its aid. The quantum theory cannot explain interference.

16. Prof. W. Duane.—*On Secondary and Tertiary Radiation.*

This paper gives the results of recent experiments on secondary and tertiary radiation carried on in our laboratory by Doctors Allison, Clark, and Stifler. The experiments with an X-ray tube in one large room radiating through a hole in the wall into a second room that contains the X-ray spectrometer indicate the presence of scattered radiation, fluorescent radiation, and tertiary radiation only, in the beam of X-rays coming from a secondary radiator. The tertiary radiation has the short wave-length limit that would be expected if it were due to the bombardment of photo-electrons. No other radiation comparable in intensity with these three types appears in the spectra. In case the X-ray tube lies in a small box, the influence of the walls of the box on the spectra is discussed.

Experiments also are described illustrating the reflection by a crystal of X-rays characteristic of the chemical elements in the crystal itself, and the precautions necessary to procure photographic evidence of this characteristic reflection are mentioned.

By placing sheets of copper in the path of the X-rays incident on the crystal sufficient in thickness to cut off practically all the radiation having wave-lengths of the characteristic line spectra of the crystal, it has been shown that this phenomenon cannot be regarded as an increase in the reflecting power of the crystal for certain rays already existing in the primary beam, but must be due to the fluorescent radiation generated in the crystal itself by X-rays of much shorter wave-lengths.

17. Prof. J. C. McLennan, F.R.S.—*Recent Developments in Low Temperature Research.*

(A visit to the Cryogenic Laboratory, by kind invitation of Prof. McLennan, was paid during the meeting. Liquid helium and the luminescence of solid nitrogen, among other things, were exhibited.)

18. Joint Discussion with Section G on *Optical Determination of Stress.*

Cosmical Physics Sub-section.

19. Mr. F. J. W. Whipple.—*The Diurnal Variation of Pressure: Facts and Theories.*

The regular oscillation of pressure shows remarkable regularities all over the globe, and it is, therefore, probable that it is connected in a simple way with its cause. The object of this paper is to emphasise the fact that there is an opening here for speculation as well as for more analysis of the records. The preparation of critical tables of pressure at places where barographs have been maintained for long periods requires international co-operation. Observational material is exceptionally rich in the British Isles, where a number of photographic barographs properly compensated for temperature changes and with open time-scales have been in operation for more than fifty years. The British records indicate that the average diurnal variation of pressure for a given time of year can be regarded as due to the combination of a local wave (a pure sine-curve) and a planetary wave. The planetary wave is not a pure sine curve; the changes in its form conform closely to changes in the sun's declination. It is pointed out that these facts are difficult to reconcile with Lord Kelvin's resonance hypothesis, and in conclusion other objections to that hypothesis are also mentioned.

20. Prof. W. J. Humphreys.—*The Relation of Wind to Height.*

On the average, perhaps, and especially on the equatorial side of cyclones, the wind varies as follows with height: Increases rapidly, but decreasingly so, with height up to 400 to 500 metres above the surface; then decreases slightly through, say, 300 metres; after this increases a little, and then remains, roughly, constant up to round 2,000 to 3,000 metres above the surface; here again often slightly decreases; and then through the next several kilometres increases in proportion to decrease of density. Directions of the wind and its temperature also are interestingly related to height above the surface.

All these observed facts are plausibly explained as effects of mechanical and thermal turbulence.

21. Mr. J. Bjerknes.—*The Importance of Atmospheric Discontinuities for Practical and Theoretical Weather Forecasting.*

Empiric investigations show that new-formed depressions usually consist of two oppositely directed air currents, the one warm and the other cold. Initially each current occupies about one-half of the region covered by the depression. The area of the cold air is, however, always increasing, and finally it embraces the whole of the depression in the lower layers. The warm air covers at the ground a correspondingly decreasing space (the warm sector). During the development of the depression, air from the warm sector will escape upwards and spread in higher layers. This motion involves a transformation from potential into kinetic energy (strengthening of the wind and deepening of the depression). The kinetic energy of the depression decreases again as soon as there is merely cold air supply available for the ascending motion. The temperature distribution in the depression thus gives useful indications concerning the expected development.

The result may be formulated mathematically as an equation giving the acceleration of the different air masses relatively to each other. One may thus, at least theoretically, arrive at a mathematical forecast, provided that sufficient observational data are at hand. This is exemplified in a depression passing Central Europe on February 1, 1923.

22. Mr. L. F. Richardson.—*Turbulence and Temperature-gradient among Trees.*

The writer has previously derived from theory a criterion for the increase of turbulence, applicable at a height in the free air great compared with the irregularities of the ground. By contrast the present investigation relates to

observations made among trees. The temperature gradient was measured by a pair of thermo-junctions placed at different heights. This is compared with the gustiness as shown by a Dines pressure-tube anemometer.

23. Dr. H. Jeffreys.—*Tidal Friction.*

24. Discussion of observations, &c., made by Meteorological party during journey from England to Canada on R.M.S. *Caronia.*

(*a*) Mr. M. A. Giblett.—*Remarks on the Daily Weather Charts constructed from data received by Wireless.*

(*b*) Mr. L. F. Richardson.—*Measurements of Up-gradient of Temperature in the Air at Levels below the Mast-head of the Ship, using an Electrical Resistance Thermometer.*

(*c*) Mr. F. J. W. Whipple.—*The Measurement of True Air Temperature and Humidity at Sea.*

A comparison of readings of screened and unscreened thermometers with those of an Assmann aspiration psychrometer in various positions on the ship.

(*d*) Dr. J. S. Owens.—*Haze Observations.*

A white haze observed on the St. Lawrence in the neighbourhood of Anticosti Island shortly before sunset was found to consist of hygroscopic salt particles, although readings of an Assmann psychrometer showed the air to be relatively dry. [An apparently similar haze observed later over Lake Ontario was found to consist of solid particles, almost certainly soot.]

Monday, August 11.

25. Presidential Address by Prof. Sir William Bragg, F.R.S., on *The Analysis of Crystal Structure by X-rays.* (Page 34.)

26. Joint Discussion with Section B on *Crystal Structure,* including the following papers:—

(*a*) Prof. W. L. Bragg, F.R.S.—*The Relation between Crystal Structure and Refractive Index.*

When an electromagnetic wave passes through a medium the electric field polarises the atoms, their positive and negative components being displaced from the normal configuration. This creates a field around each atom equivalent to that of an electric doublet whose moment is proportional to the electric vector at each instant. The velocity of the wave in the crystal depends on the ratio between the total polarisation per unit volume and the field.

Each atom is affected by the general field and by its polarised neighbours. In a crystal which has been analysed by X-rays the effect of neighbouring atoms on each other can be calculated. The double refraction of Calcite and Aragonite, for instance, can be satisfactorily explained quantitatively. This holds for other crystals, and similar calculations are of interest when applied to gases.

It appears probable that a better measure of atomic refractivity will be arrived at when due allowance is made for atomic arrangement.

(*b*) Prof. C. H. Desch, F.R.S.—*The Crystal Surface.*

The atoms in a crystal being arranged on a space lattice, all atoms in the interior of the crystal must be held in position by forces symmetrically disposed. At the surface of the crystal this symmetry disappears, so that the surface layer of a crystal must possess properties different from those of the mass. A part of

this difference manifests itself as surface tension. With increase of temperature, the cohesion and the surface tension in general diminish, but not necessarily at the same rate. At high temperatures, the surface tension may be sufficient to cause rounding of the sharp angles of a crystal. This is shown by experiments with gold. Beads of gold, slowly cooled from the liquid state, have a skin which has properties like those of a film of gelatin, the normal structure being exposed when the film is removed by etching. The sharp octahedral 'etch-figures' on large crystals of gold, or the angles of minute crystals prepared by precipitation, become rounded at temperatures several hundred degrees below melting-point. Other effects of surface tension in solid metals are given.

(c) Dr. G. Shearer.—*The Chemical and Physical Significance of X-ray Measurements of Compounds containing Long Chains of Carbon Atoms.*

Such measurements appear to give reliable values for the lengths of these molecules; they show that the basis of the structure is actually a chain of carbon atoms which may have one or other of a limited number of forms. The observed rates of increase of the lengths of the molecules with the number of carbon atoms they contain are in accordance with the assumption that successive pairs of carbons are linked together at the tetrahedral angle; this would imply a marked directive property of the valency bond in carbon. The method of investigation would appear capable of throwing light on many problems of stereochemistry—geometrical isomerism, the nature of double and triple bonds, &c. The existence of spacings often as great as 60 A.U. makes it possible to observe a large number of successive orders of reflection, and a study of the intensity distribution among these different orders is of interest.

(d) Prof. W. L. Bragg, F.R.S., and Prof. S. Chapman, F.R.S.—*A Theoretical Calculation of the Rhombohedral Angle of Calcite.*

The paper describes an attempt to calculate theoretically the rhombohedral angle, or axial ratio, of crystals of the calcite type. A number of carbonates form rhombohedral crystals similar to calcite, which can be referred to three equal axes. The angle between the axes is in the neighbourhood of 102° for the whole series.

There must be some fundamental reason for the occurrence of this angle throughout the series. The crystals consist of ions R^{++} and CO_3^{--}, where R may be Mg, Ca, Mn, Fe, Co, Ni, Zn, Cd. One can picture the rhombohedral crystal symmetrically extended or compressed along a trigonal axis, keeping constant the distance between neighbouring oxygen and metal centres, and neighbouring carbon and oxygen centres. The electrostatic potential energy per gram-molecule has been calculated for a series of such positions, and it has been found that it has a minimum value in the neighbourhood of 106°. Taking into account the approximate nature of the assumptions on which the calculation is based, this may be regarded as in satisfactory agreement with the observed value of 102°. Further, it is possible to calculate the effect on the rhombohedral angle of substituting other metal ions for calcium, and it has been found that the slight variation in angle, which is 101° 55′ in $CaCO_3$ and 103° 2′ in $MgCO_3$, is accurately explained.

(e) Mr. W. T. Astbury.—*The Determination of Molecular Symmetry in Crystals and its Possibilities as a Method of Deriving Structural Formulæ.*

Given the class of any crystal, we can, with two exceptions, decide definitely the space-group, and thence, from the number of molecules per cell, derive the only symmetry elements possible to the molecules as they are built into the crystal. Then, by a critical examination of the dimensions of the cell and the relative positions of the molecules within it as given by the space-group, it is often possible to make a clear choice between two or more suggested structural formulæ, even though the molecule be fairly complex. But, in general, it is essential to know from chemistry the various possibilities. The molecular symmetry in the crystal is in general less than what would be expected of a

molecule in the free state. A brief account will be given of the application of this method to the problem of the isotrimorphism of the tervalent metallic acetylacetones and the structure of the acetylacetone group.

(*f*) Mr. S. H. Piper.—*X-ray Crystallographic Methods as an Aid to Chemical Research.*

(*g*) Prof. W. L. Bragg, F.R.S.—*Exhibit of Models illustrating Crystal Structure.*

27. Prof. V. Bjerknes.—Lecture on *The Forces which Lift Aeroplanes.* (Illustrated by experiments.)

Now that aviation has become a reality much work is being expended upon the investigation of the hydrodynamic forces which make flying possible. The result has in one respect been surprising : these forces are seen to belong to an extensive class which was investigated long before the period of aviation in connection with a totally different problem, that of action-at-a-distance.

After Newton's discovery of universal gravitation, action-at-a-distance was for two centuries the leading idea of natural philosophy. But a decided change of our ideas came about thirty years ago, after a development connected with the names of Faraday, Maxwell, and Hertz. In the period before this reversal had taken place C. A. Bjerknes, the father of the lecturer, found, first by mathematical investigations and later by experiments, that spherical and cylindrical bodies moving in a fluid exert apparent action-at-a-distance upon each other. These actions form part of a remarkable analogy which exists between hydrodynamic and electromagnetic phenomena. After the theory had been generalised by the lecturer, and made independent of every special supposition concerning the form of the bodies, this analogy may now be stated thus :

1. Regarding geometric structures full identity can be established between hydrodynamic fields of motion and static or stationary electromagnetic fields of force.

2. The mechanical forces which act in corresponding hydrodynamic and electromagnetic fields are oppositely equal to each other.

This direct geometric and inverse dynamic analogy can be illustrated by striking experiments. Regarding the apparent actions at a distance, the experiments will show the following phenomena, the opposite sign of the forces being tacitly understood : pulsating bodies act upon each other as if they were electrified, oscillating bodies as if they were magnets; neutral bodies take induced oscillations from the fluid and become subject to the same forces as iron and bismuth; rotating cylinders act upon each other like electric currents.

The forces which act upon the rotating cylinder are the same as those that carry the wing of an aeroplane. Theoretically the simplest aeroplane should have rotating cylinders instead of rigid wings. The lift depends upon the circulation of the air round the wing. We produce and regulate at will the required circulation by rotating the cylinders, while in the case of the common rigid wings we get it by a spontaneous process.

Cosmical Physics Sub-section.

28. Dr. J. S. Owens.—*The Automatic Measurement of Atmospheric Pollution.*

Refers especially to results of the automatic recorder designed by the author for the Advisory Committee on Atmospheric Pollution. The function of this is to measure the pollution of city air by smoke. A short description and references to fuller descriptions are given. The results obtained in London by this apparatus are compared with those of the author's dust counter (*Proc. Roy. Soc. A.*, Vol. 101, 1922) and show a good correspondence. Curves obtained by both methods in investigating the effect of suspended matter on obstruction of light are given; the relation between obstruction and dust content is shown

to be nearly a straight-line one. From this comparison it appears that 1 milligramme of dust per cubic metre has the same effect as about 10,000 particles per cubic centimetre; thus 10^{10} smoke particles weigh 1 mg. approximately. The size of suspended dust particles is fairly uniform, but tends to increase during smoke fogs, probably due to their rapid formation giving insufficient time for grading by settlement.

29. Mr. J. Patterson.—*Upper-Air Observations in Canada.*

Upper-air observations were commenced in Canada in 1911, but were partially interrupted by the war. It has not yet been possible to get balloons for carrying instruments equal to those of pre-war days; there are, however, good prospects of overcoming this handicap in the near future. During the past year an automatic apparatus for calibrating the meteorographs has been installed and the Dines meteorograph simplified. The results of the sounding balloon ascents during the past five years and the observations with pilot balloons in the Arctic will be discussed, together with the prospects of permanently extending the field of observations in the upper air to this region.

30. Prof. H. H. Kimball.—*The Determination of Daylight Intensity from Automatic Records of Total Solar and Sky Radiation.*

Colour temperatures of sunlight and skylight, and the spectrum energy curves of radiation from the sun and from the sky, have been utilised to determine approximately the spectrum energy curve of the total radiation received on a horizontal surface, and its variation with atmospheric transmissibility and the solar zenith distance.

A comparison of these latter curves with the curve of 'visibility of radiation' permits a prediction to be made of the variations to be expected in the ratio between the intensities of the vertical components of daylight and of the total solar and sky radiation.

This ratio has also been determined experimentally by comparing photometric measurements of daylight illumination on a horizontal surface with continuous records of the total solar and sky radiation made by a U.S. Weather Bureau thermoelectric pyrheliometer horizontally exposed.

The above investigations have been confined to skies that were either cloudless or else completely covered with clouds.

31. Prof. W. J. Humphreys.—*Rainmaking.*

Several of the more persistently urged schemes for producing rain are considered in respect to the underlying principles involved, and measured quantitatively to determine the question of their practical use.

These schemes include, especially: the production of loud noises; the use of chemicals; mechanical or forced convection; fog-collecting screens; dusting the sky; spraying liquid air on to clouds, and sprinkling clouds with electrified sand.

None of these rainmaking methods is practicable in the commercial sense of the term; but each, when treated quantitatively, is full of meteorological interest.

32. Prof. C. F. Marvin.—*Let us Simplify the Calendar and Publish Statistical Data in Standardised Summaries.*

Great masses of statistical data covering the fields of meteorology, yields and prices of crops, business and economic conditions, panics, &c., are now being annually accumulated.

To be fully useful to students for analysis in any of these fields these data need to be appropriately assembled, summarised in suitable units of time and sectional area or representative groups, and promptly, regularly, and systematically published. This is not now being done sufficiently, either with reference to much available data of past years or comprehensively for the future.

Our complex and awkward calendar, with months of unequal lengths made up of four weeks plus 0, 1, 2, or 3 days, apportioned according to the envy

and whim of an old Roman Emperor, absolutely prohibits orderly and rational summaries of statistical data in suitable units of conveniently increasing time.

Let us promote the adoption of the simple equal-month calendar many others are now advocating, and thus make it easy, for all future time at least, to summarise data in units of weeks, fortnights, four-week months, thirteen-week quarters, and years of fifty-two exact weeks. It is an easy matter to absorb the unavoidable extra day in common years and the two such extra days in leap years.

Publication of detailed data *in extenso* is generally prohibitive because of the enormous mass available, and because investigators cannot undertake the huge task of making the necessary summaries. It is hoped and recommended that the meteorologists may set a good example to scientists dealing with great bodies of statistical data, by helping to secure calendar simplification, and to agree upon some standard superficial units of continental areas for which summaries of standard and representative data should be published.

These ideas have reference very largely to starting a system at the present time that will bring great benefits to future generations and posterity. To reap these same benefits ourselves we must wipe out the awkward summaries of back data we now use, and compute new summaries on the simplified-calendar basis. It will suffice if this be done for simply the major meteorological elements, and when we recall that the task might easily be apportioned among the many thousands of observers constantly on duty, the desired result can easily be attained.

Tuesday, August 12.

33. Prof. R. W. Wood, For. Mem. R.S.—*Controlled Orbital Transfers of Electrons in Optically Excited Mercury Atoms.*

Mercury vapour at room temperature is illuminated by radiation of wave-length 2536 in combination with monochromatic radiation of one or more other wave-lengths corresponding to arc lines of mercury. In this way electrons, brought to the $2p_2$ orbit by the absorption of 2536, can be carried to one or more known outlying orbits, and certain of the mercury arc lines are radiated and can be photographed. From intensity measurements of the lines statistically data can be directly obtained regarding the probability of certain orbital transfers.

Most remarkable of all is the effect of additions of small traces of nitrogen to the mercury vapour. This caused a powerful emission of the so-called water-band in the ultra-violet, a thirty-fold increase in the intensity of emitted green radiation (2536), and the introduction of an absorbing power for the violet line 4046 (which is not absorbed by the excited vapour in vacuo) so great that the line is practically suppressed when the light of the arc is passed through a layer of vapour 5 cm. in thickness.

34. Discussion on *The Scattering of Light.*

(*a*) Prof. C. V. Raman, F.R.S.—*The Scattering of Light in Relation to the State of Molecular Aggregation.*

The paper summarises recent work carried out by the writer and his students with the aim of comprehensively studying the dependence of the light-scattering power of a substance on the state of aggregation of its molecules. Various theoretical questions which arise are also discussed.

1. Experiments on the scattering of light by gases and gaseous mixtures at high pressures have been made (with Mr. L. A. Ramdas). Oxygen, carbon dioxide, and mixtures of these gases at pressures ranging from 1 to 150 atmospheres have been used. The variation of the scattering power under different conditions is best discussed with the aid of the thermodynamic surface representing the properties of the mixture.

2. Light-scattering in liquids and in the corresponding vapours has been studied (with Mr. S. Krishnan and Mr. A. S. Ganesan respectively). Some seventy liquids, mostly organic compounds, have been investigated, and also the corresponding vapours as far as practicable. The comparison between vapour and liquid furnishes a valuable test of theories of light-scattering.

3. The transition from the liquid to the amorphous or glassy condition at low temperatures may be investigated by the method of light-scattering. The bearing of the results on the nature of the amorphous state is discussed.

4. Observations have also been made on the scattering of light in transparent crystals.

5. The relation of molecular anisotropy to natural and artificial double refraction, and to chemical constitution, is discussed.

(*b*) Prof. F. B. Kenrick.—*Light-Scattering of Aqueous Salt Solutions.*

The light-scattering and depolarisation factors have been measured for aqueous salt solutions prepared dust-free by the method of envelopment. The intensities of scattering are compared with the calculated values.

(*c*) Prof. W. H. Martin.—*The Relation between the Depolarisation Factor of the Scattered Light and the Electrical Double-Refraction in Liquids.*

Richard Gans' theory of the relation between the depolarisation factor of the scattered light and the Kerr constant of electrical double-refraction in liquids is submitted to experimental test for some fifteen liquids. Measurements of the depolarisation factor for nitrobenzene made in a magnetic field of 5,000 gauss failed to show any change in the polarisation of the scattered light.

35. Prof. L. B. Loeb.—*Gas Ion Mobilities and their Independence of the Nature of the Ion.*

If an expression deduced by J. J. Thomson (*Phil. Mag.*, 47, p. 345) for the shortening of the free path of a gas ion acting on neutral molecules according to an inverse fifth power law of force be introduced into the Langevin equation for the mobility of a gas ion, it can be shown that K, the mobility of the ion, is given by

$$K = \frac{\cdot 815}{[2\pi N_0 \mu]^{\frac{1}{2}}} \quad \frac{\sqrt{\frac{b+1}{b}}}{\frac{p}{760}\sqrt{(D-1)M_0}}$$

Here N_0 is the number of molecules per c.c., μ is the mass of an H atom, p is the pressure of the gas in which the ion moves in mm., D the dielectric constant of the gas, M_0 its molecular weight, and b is the number of gas molecules in the ion.

It is seen that except for the factor $\sqrt{\frac{b+1}{b}}$ (which varies from 1.4 to 1.0), K is independent of the nature of the ion. K is a function of p, M_0, and D, but does not depend on the velocity of thermal agitation of the ion nor its free path. This is all in accord with experiment. The absolute values of the mobilities computed from the equation are in better agreement with observed values than those of any existing theory.

36. Prof. Sir Ernest Rutherford, F.R.S.—*Lecture on Atomic Disintegration.*

Cosmical Physics Sub-section.

37. Rev. A. L. Cortie.—*The Relation between Solar Activity and Terrestrial Magnetic Disturbance.*

1. A sun-spot of very great area is always accompanied, at some stage of its life history, by a magnetic disturbance. For instance, in the solar cycle

1913-1924 just completed, the maximum sun-spot, 1917, August 11, was accompanied by a violent magnetic storm, as was also the great sun-spot group of 1920, March 22-24. But there is no parity between the size of a sun-spot and the character of the concomitant magnetic disturbance. Great activity is more effective than great area in sun-spots. An example is the very great magnetic storm of 1919, August 11-13, which accompanied a relatively small, but very active spot, and the moderate magnetic disturbance which occurred when a very much greater sun-spot group was on the sun's disc, 1919, August 19.

2. The terrestrial magnetic disturbances are more numerous after the maximum phase of sun-spot activity in a cycle. From the numbers of moderate, great, and very great disturbances, mean magnetic 'character' figures have been derived, which are compared with the mean disc-areas of the sun-spots in the following table :—

Year	Disc-area Spots	Magnetic Character	Year	Disc-area Spots	Magnetic Character
1912	0·20	0·05	1918	7·90	0·27
1913	0·04	0·06	1919	8·40	0·39
1914	0·82	0·07	1920	4·05	0·26
1915	4·51	0·12	1921	3·14	0·26
1916	4·52	0·20	1922	1·73	0·45
1917	12·10	0·14	1923	0·37	0·19

The phenomenon is apparent in the last three solar cycles. It is also brought out in the well-established twenty-seven day period in terrestrial magnetic disturbance, which is much more developed with a low sun-spot frequency, and a low latitude of the spots. In individual storms of greater violence it is shown in those of 1920, March 22, and 1921, May 13-14.

3. Magnetic disturbances of considerable activity may occur at a period of solar calm, when there are no sun-spots, or even faculæ, visible on the sun's disc. Examples in the last cycle are the disturbances of 1923, March 23-25, and of 1924, January 29-30. Such storms are connected with the synodic presentment to the earth of solar areas, which had been previously disturbed by sun-spots. They remain intermittently effective, so far as their relation to terrestrial magnetism is concerned, even after the spots have disappeared.

38. Mr. E. A. Hodgson.—*Correlation of Records of two Distant Milne-Shaw Seismographs.*

The Milne-Shaw seismographs, Nos. 17 and 23, of the Dominion Observatory, were used experimentally in 1923. No. 17 was kept in constant position to register the E-W component. The constants were the standard set recommended by the makers with the magnification set at 250-fold. No. 23 was first kept on the same pier and a series of records made with the constants standard and then with all standard except the damping ratio, which was varied, after several earthquakes had been recorded at each setting. No. 23 was then set up at Shirley Bay, Ont., about eight miles, approximately, west of the Observatory. It was set to record the E-W component, and the constants were kept standard. Time was checked by wireless communication with the Observatory, the same time signals being recorded on the two instruments. The Tokio earthquake was recorded in this experiment. The instrument was next set up at Kemptville, Ont., about thirty-five miles, approximately, south of Ottawa. The same experiment was repeated. A severe micros storm was secured on both instruments and about twenty earthquakes. Time was checked by wireless signals from Annapolis. The paper will deal with the peculiarities of the instruments with respect to one another and the correlation of particular phases as recorded on the widely separated instruments. It will be fully illustrated by lantern slides and copies of the records.

39. Mr. J. J. Shaw.—*Report of the Seismology Committee.*

40. Mr. A. Thomson.—*Upper Wind Observations at Samoa*, 1923-24.

Pilot balloon observations were initiated at Apia Observatory in June, 1923, and have been continued to the present time. The Observatory is situated in the western part of the South Pacific Ocean in a region so remote from the continental areas of South America and Australia and the island groups of Tonga and Fiji that land masses must necessarily exert only a slight influence on the air currents.

Observations were made by the single theodolite method on balloons inflated to rise at the rate of 180 metres per minute.

The fifty-five balloon flights which reached heights greater than 5 km. were grouped in two periods: the dry or trade wind season from June to October, and the wet season from November to April. The results from the two periods were similar. From 1 to 4 km. there was a slight decrease of velocity, and from 4 to 12 km. a steady increase. At 12 km. the velocity had a maximum value, and if the region of maximum velocity corresponded to the tropopause, as in temperate latitudes, then the stratosphere was considerably lower than might have been expected.

The easterly or trade wind component decreased from 5.8 m.p.s. at the surface to zero at 2.5 km., above which westerly winds persisted to the limit of observation. The north or south component was always small.

41. Dr. W. Bell Dawson.—*Effect of Wind on the Tide.*

The estuary of the St. Lawrence and the Bay of Fundy lie parallel to the storm tracks along the eastern coast of North America. The Tidal Survey has now observations of the tide during many years in these regions, and simultaneous meteorological record. There is thus an exceptional opportunity for the investigation of the effect of the wind in raising the tide, if this material could be worked up.

Wednesday, August 13.

42. Joint Discussion with Section B (*q.v.*) on *Colloids.* (Page 378.)

Cosmical Physics Sub-section.

43. Prof. A. S. Eddington, F.R.S.—*Theory of the Outflow of Radiation from a Star.*

The outward flow of radiation through a star depends on the temperature-gradient (strictly the gradient of T^4) urging the flow, and on the absorption-coefficient or opacity resisting the flow. The temperature distribution is determined by the conditions (1) that it must be such as to maintain itself automatically, (2) that the resulting pressure must support the material against gravity. Very general considerations as to the processes involved in absorption indicate that the opacity will be approximately proportional to $\rho/T^{\frac{7}{2}}$. In this way formulæ are obtained giving the total outflow of radiation from a star of given mass and density, provided that it is constituted of perfect gas; the total radiation depends mainly on the mass, the density making comparatively little difference. The observational data fit these formulæ very closely. The surprising thing is that a great part of the data refer to stars of density greater than water; it is suggested that these stars agree with the theoretical results for a perfect gas because the atoms, being broken up by intense ionisation, approximate closely to the ideal point-molecules of a perfect gas. The conclusions conflict with the giant and dwarf theory of stellar evolution.

44. Mr. E. A. Milne.—*Radiation Pressure and the Equilibrium of the Solar Chromosphere.*

The variation of density with height in the solar chromosphere must depend intimately on the relative extents to which the atoms are supported against gravity by radiation-pressure and by the gradient of the gas-pressure. Let

μ denote the limiting value, at great heights, of the fraction of the weight which is balanced by the pressure gradient. Unless μ is extremely small, the density decreases upwards approximately according to an exponential law. But if $\mu=0$ (*i.e.* if, at great heights, the whole of the weight is balanced by radiation-pressure), the density ρ at height x, for a gas with the properties of ionised calcium, is found to be given by $\rho=(\text{const.})/(x+x_0)^2$, where x_0 is the height of the equivalent homogeneous atmosphere. This gives a comparatively slow decrease of density with height, in marked contrast with exponential laws. Comparison with observation shows that for ionised calcium atoms in the solar chromosphere μ can scarcely be as large as 0.01.

45. Dr. L. SILBERSTEIN.—*Determination of the Curvature Radius of Space-Time.*

Assuming de Sitter's space-time, as determined by the line-element

$$ds^2 = \cos^2\sigma \,.\, c^2dt^2 - dr^2 - R^2 \sin^2\sigma(d\varphi^2 + \sin^2\varphi d\theta^2)$$

with R written for the curvature radius and $\sigma = \frac{r}{R}$ and considering both the observed star and the observer's station as 'free particles' in radial, purely inertial motion, a formula is deduced for *the complete Doppler effect* or spectrum-shift $D = \frac{\delta\lambda}{\lambda}$ by comparing the segments of the observer's and the star's world-lines intercepted by two minimal lines representing light signals sent from the star to the observer. The rigorous result is

$$D = \gamma\,[1 \pm \sqrt{1 - \cos^2\sigma/\gamma^2}] - 1 \qquad . \quad . \quad . \quad . \quad (1)$$

where $r = R\sigma$ is the observer's distance from the star at the instant of receiving its light. The upper sign corresponds to a receding and the lower to an approaching star, giving a red and a blue shift respectively.

In a first approximation at a determination of the radius R from the most remote objects of the sky for which both D and r values are available, the formula becomes

$$D = \pm\frac{r}{R}$$

the co-ordination of signs being as before. No distance estimates being as yet available for the spiral nebulæ, this formula is applied to eight globular clusters and the two Magellanic Clouds, and gives an arithmetical mean of

$$R = 6{\cdot}7 \times 10^{12}$$

astronomical units.

Formula (1) is extended to any, generally oblique, inertial motions. If r_0 be the shortest distance (perihelion) of the star and v_0 the corresponding velocity, the rigorous general formula reduces practically to

$$D^2 = \left(1 - \frac{r_0^2}{r^2}\right)\left(\frac{r^2}{R^2} + \frac{v_0^2}{c^2}\right) \qquad . \quad . \quad . \quad . \quad . \quad (2)$$

This is applied to the previous objects and to ten more clusters and one spiral nebula (the data for which were obtained quite recently), in all twenty-one objects, and yields, statistically, the radius

$$R = 7{\cdot}72.10^{12}.$$

46. Dr. H. H. PLASKETT.—*The Spectra of Nebulæ.*

The paper discusses some new observations on the spectra of nebulæ. These new observations furnish the *absolute* intensities of the hydrogen and some 'nebulium' lines as determined by the wedge method in the Orion Nebula, partially confirm the previous interferometer results in assigning a low atomic weight to 'nebulium,' and finally contain a complete description of the new

gaseous envelope star Z Andromedæ, discovered at Victoria. In the discussion these and the much more numerous earlier observations are treated in an attempt to determine (*a*) the mode of excitation of the nebular radiation and (*b*) the nature of the carrier of the 'nebulium' spectrum, in particular if it is a H He molecule.

47. Mr. J. Jackson.—*Photographic Proper Motions of Faint Stars.*

During the past year the Zone centred at 65° N.Dec. has been photographed with the 13-inch astrographic telescope at the Royal Observatory, Greenwich, for the determination of proper motion by comparison with the original astrographic plates taken about thirty years ago. The new plates are taken through the glass—*i.e.*, with the film side of the plate away from the object glass of the telescope. The new and old plates are then placed film to film and the relative position of the stars measured. All the plates on this Zone have now been measured, so that it is possible to deduce the proper motion of all stars between 64° and 66° N.Dec. down to about the twelfth magnitude. Most proper motions of the order of 3″ a century can be detected with certainty. The following short table shows the number of stars found with a proper motion exceeding 5″ a century in the second half of the Zone R.A. 12h. to 24h. :—

Centennial Proper Motion.

No. of stars in Catalogue	5″–10″	10″–15″	15″–20″	20″–30″	30″–50″	50″
10,192	533	87	38	20	10	1

The results are being discussed for systematic motion of the stars.

48. Dr. R. K. Young and Dr. W. E. Harper.—*Methods and Results of Spectroscopic Absolute Magnitude Determinations.*

The paper presents the results of an investigation into the methods of determining parallaxes by the spectroscopic method and gives results for 1,105 stars. The spectra of 500 stars of known parallax were used to calibrate the empirical curves relating line intensity to absolute magnitude; new lines showing the effect were found, and fourteen have been used in the work. A standard scale showing absorption lines of graded intensity was used in estimating line-ratios. Proper motions were used as a check upon the results of groups of stars. Substantial agreement exists with Mount Wilson except in the late K-giants, where we have a greater range in brightness.

49. Dr. F. Henroteau.—*The System of σ Scorpii.*

As a result of several years' study, it appears probable that σ Scorpii is an interesting triple system. First it was found by Father Selga that a considerable variation of radial velocity existed, having a very short period (about six hours). The star is thus of the β Canis Majoris type or, as we have reason to suppose, an extreme case of Cepheid variation. The short-period radial velocity variation cannot be attributed to orbital motion.

A longer period of radial velocity variation (about thirty-four days) due to orbit motion was then discovered, long-period curves being determined in the years 1918, 1920, 1921, 1922, 1923, and 1924. Remarkable changes of shape and amplitude occur in them. Theoretical researches made in 1921 indicate that large perturbations in the orbit could not be due to a possible non-spherical shape of the primary body.

At present we find indications of the existence of a more remote third body—that is, of a motion in a longer period orbit (probably in the neighbourhood of five years). This is found not from the variation of radial velocity, but from the fact that the maxima or minima of the short-period radial velocity curves come some years sooner, other years later, than the predicted ones; in other words, there is a very marked equation of light which from its variation permits us to compute elements of the long-period orbit.

σ Scorpii may thus be considered as a Cepheid in a triple system, a case unique at present, which from the fact that it shows remarkable perturbations may bid fair to throw important light on the problem of Cepheid variation.

50. Mr. R. Meldrum Stewart and Mr. J. P. Henderson.—*Wireless Time Signals.*

The time signals emitted by Annapolis and Lafayette have been regularly observed at Ottawa for some years. A summary of the comparisons of time thus obtained between Ottawa, Washington, and Paris is given.

The comparisons have usually been made by the method of coincidences by extinction, in which the incoming wireless signals are gradually encroached upon and finally obliterated by the opening of a relay operated by a differentially rated chronometer.

Comparisons have been made between observations by the above method and those by actual chronographic registration; the latter were also studied independently. It appears that in the case of chronographic registration the greatest precautions must be taken to avoid the introduction of variable relay lags, especially differences in lag between the incoming signals and the artificially introduced clock signals. Apart from photographic methods, and possibly those involving the use of a syphon recorder, the only satisfactory method appears to be the use of a relay of speed comparable with that of the audio valve oscillations, coupled with another relay in such a way as to ensure the carrying through to the chronograph of even a single pulsation of the primary relay. Even under such conditions the accuracy of chronographic recording appears to be no higher than that of the coincidence method, and the latter has the advantage that observations can be made of fainter signals.

SECTION B.—CHEMISTRY.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 465.)

Thursday, August 7.

1. Presidential Address by Sir Robert Robertson, F.R.S., on *Chemistry and the State.* (Page 53.)

2. Prof. W. A. Bone, F.R.S.—*The Activation of Nitrogen in the Explosion of Carbon Monoxide-Air Mixtures at High Initial Pressures.*

The paper describes the principal experimental results obtained by the author in conjunction with Messrs. D. M. Newitt and D. T. A. Townend during the recent researches upon gaseous combustion at high pressures, in which it has been discovered that nitrogen exerts a peculiar energy-absorbing influence when carbon monoxide-air mixtures are exploded in a bomb at high initial pressures, which is not manifest at all when corresponding hydrogen-air mixtures are similarly exploded. The observed facts are explained on the supposition that there is some constitutional correspondence between CO and N_2 molecules (where densities are identical) whereby the vibrational energy (radiation) emitted when the one burns is of such a quality as can be readily absorbed by the other, the two thus acting in resonance. The nitrogen thus becomes chemically 'activated' in carbon monoxide-air explosions at high initial pressures, and in such state is able to combine with oxygen more readily than does nitrogen which has merely been raised to a correspondingly high temperature in a hydrogen-air explosion. The influence of varying *initial* explosion pressures up to 100 atmospheres upon the said 'nitrogen-activation' is shown, and the bearing of the results upon the problem of 'nitrogen-fixation' discussed.

3. Prof. James Kendall and Mr. Beverly L. Clarke.—*A New Method for the Separation of Elements of the Rare Earths.*

The ionic migration method previously proposed for the separation of isotopes [*Proc. Nat. Acad. Sci.* 9, 75 (1923)] has been successfully extended

to the fractionation of certain rare earth mixtures. A gel containing the given mixture is placed in a long glass tube, between a section of KCl gel (nearer the anode) and a section of chromic sulphate gel (nearer the cathode). On electrolysis, since the K^+ moves more rapidly than the rare earth ions, and the Cr^{+++} moves more slowly, the two boundaries of the central section remain quite sharp even after it has travelled a long distance. If the rare earth ions themselves have appreciably different mobilities, the faster ion should accumulate in the front portion and the slower in the rear portion of this section, so that a complete separation should readily be obtained. Short runs have been carried out with three mixtures—yttrium-erbium, gadolinium-samarium, and neodymium-praseodymium. In the first two cases a 400-cm. run gave practically perfect separation; in the last the separation was only partial.

4. Dr. F. W. Atack.—*Isomerism of Oximes.*

5. Prof. J. F. Snell.—*Malic Acid from Maple Sugar Sand.*

Friday, August 8.

6. Mr. D. A. Pritchard and Mr. G. E. Gollop.—*The Canadian Salt Company's Processes for the Manufacture of Alkali-Chlorine Products.*

The plant of the Canadian Salt Company at Windsor, Ontario, is situated over salt deposits of vast extent and is near enough to Niagara Falls to render the use of electric power from that source economical. The plant is also favourably located for both water and rail distribution. The first electrolytic alkali plant in Canada was installed in 1912 by this company. Details are given of the construction (illustrated by lantern slides) of the electrolytic cell used and of its operation, efficiency, &c. The cell is named after its inventor, Arthur E. Gibbs, an Englishman. In Canada, the United States, and England there have been installed to date Gibbs' cells to the capacity of approximately 45,000 h.p. Details are given of the mechanical bleach-making equipment employed, believed to be the only successful one on this continent. A complete description of the manufacture and handling of liquid chlorine, in which industry the company is the pioneer in Canada, is also given.

7. Mr. R. L. Peek.—*The Electro-Refining of Nickel.*

(Followed by General Discussion on Canadian Electrochemical Industries, Prof. F. G. Donnan, F.R.S., taking part.)

8. Mr. Horace Freeman.—*The Economic Aspect of Hydroelectric Development in Relation to Canadian National Resources.*

The present uses of hydroelectric energy for chemical and metallurgical purposes in Canada are referred to in connection with domestic and imported raw materials. The consequent growth of industrial communities in Canada. The general nature and locations of available mineral deposits, the trend of metallurgical practice, and the need of Research to meet the requirements of the situation, are dealt with. The export demand in U.S. for energy from Canada must be considered in conjunction with our ability to provide loads for present developed energy and our supplies of raw materials. The importance of the situation to British metallurgical interests is vital.

9. Mr. F. A. Lidbury.—*Characteristics of Electric Steam Generation.*

10. Mr. F. A. J. Fitzgerald and Mr. G. Kelleher.—*The Radiant Resistor Furnace.*

Described furnace, designed by the author, for heating by radiation from a resistor. The principle has since been employed by many investigators, and results were given of experimental work carried out on a rather large scale. Numerous instances were given in detail.

Monday, August 11.

11. Joint Discussion with Section A (*q.v.*) on *Crystal Structure.* (Page 365.)

12. Joint Discussion with Section I (*q.v.*) on *Vitamins.* (Page 429.)

Tuesday, August 12.

13. Joint Discussion with Section C on *Liquid and Powdered Fuels.*

(*a*) Dr. G. S. Hume.—*Liquid Fuels in Canada.*

The production of oil in 1923 in Canada was obtained from wells in New Brunswick, Ontario, and Alberta, but was only 1.3 per cent. of the total consumption of crude and refined oils for the same time, representing an adverse trade balance of nearly $31\frac{1}{2}$ million dollars. Such a condition has greatly stimulated boring operations within the last few years, and tests of prospective fields have been made in many places, the most promising results being obtained in Alberta. However, even though a certain increase in production is possible from wells, the consumption is so far in excess of production that the probabilities of making Canada independent of foreign oil supply in the near future from this source alone are not very great. Canada, however, possesses immense potential resources of oil in the tar sands of Alberta and the oil shales of the Maritime Provinces. The tar sands of Alberta occur over an area of 7,500 to 8,000 square miles, some portions of which give 20 per cent. bitumen carrying an oil content as high as 69 per cent. The oil shales of New Brunswick and Nova Scotia will in places produce as much as 30 to 36 imp. gals. of oil to the ton with some by-products, and the amount of oil shales available is exceedingly large. For neither of these deposits, though, has a satisfactory commercial process of extraction been evolved up to the present, although the technical difficulties are being studied by experimental work and laboratory investigation, and it is hoped a solution will be discovered.

In Nova Scotia in 1915 the Dominion Iron and Steel Co. began the recovery of benzol and toluol with other products from the coking of coal. These were used during the war for the manufacture of explosives, but subsequently have been combined as a motor fuel, the production of which reached 292,000 gals. in 1921. It is claimed that this motor fuel possesses qualities which make it superior to the best gasoline, and with the establishment of coke ovens elsewhere in Canada, such as are now under consideration, motor fuel from this source will become increasingly important.

(*b*) Prof. George A. Guess.—*Pulverised Coal in some Metallurgical Plants.*

In reverberatory smelting pulverised coal was used successfully for the first time at the plant of the International Nickel Company at Copper Cliff, Ontario, in 1914. The difficulties that had to be overcome in the use of pulverised coal in reverberatory work are described and the advantages attendant upon its use are indicated. The experience of certain smelting works with powdered coal is given, and the use of the same for steam-raising is touched upon.

(*c*) Col. H. D. Savage.—*Powdered Fuel in Locomotives.*

(*d*) Prof. W. A. Bone, F.R.S.—*Brown Coals and Lignites.*

The paper discusses (*a*) the classification of sub-bituminous coals generally, with special reference to brown coals and lignites, and (*b*) their occurrence and distribution throughout the British Empire. Attention is directed to their economic importance, and to the need of more co-ordinated research and investigation into their properties and uses with a view to developing within the Empire a scientific brown-coal technology. Some results of the author's recent investigations upon the drying, heat treatment, and carbonisation, &c., of brown coals are described from the point of view of their bearing upon the many problems which their utilisation presents to the fuel technologist.

Wednesday, August 13.

14. Joint Discussion with Section A on *Colloids.*

(*a*) Prof. J. W. McBain, F.R.S.—(1) *The Conception and Properties of the Electrical Double Layer and its Relation to Ionic Migration.* (2) *The Rate of Saponification of Oils and Fats by Alkali.* (3) *Limitations to the Use of Indicators in Alkaline Solutions and in the Presence of Soaps.* (4) *The States of Matter exemplified by Soaps and their Solutions.*

(1) *The Conception and Properties of the Electrical Double Layer and its Relation to Ionic Migration.*

Our present knowledge of the double layer between liquids and such materials as glass, membranes, and colloidal particles is reviewed, and the numerous and conflicting assumptions which have been put forward in calculating the 'contact potential' are stated explicitly. It is emphasised that the contact potentials currently employed have a fictitious significance, and it is therefore urged that experimental results be recorded in the form in which they are observed—namely, movement in an electric field or electromotive force set up by bodily movement.

A conception of the double layer with sparsely distributed mobile ions is developed which appears to harmonise the existing data, including also those for absolute electrode potentials and for the behaviour of sols, gels, and curds of soap (cf. earlier paper by Miss Laing). If this conception is a true interpretation of the existing data, the fundamental assumptions made in all previous mathematical treatment of this subject are invalid.

(2) *The Rate of Saponification of Oils and Fats by Alkali.*

It has been found possible to measure the rate of saponification of oils by means of a hydrogen electrode at 90°, and to isolate the various factors involved. The rate depends, for example, upon the amount of emulsified oil, and it is found that even with vigorous stirring only a limited proportion of the oil present is truly emulsified. Excellent monomolecular constants are obtained for the dependence of the rate on the hydroxyl ion present.

(3) *Limitations to the Use of Indicators in Alkaline Solutions and in the Presence of Soaps.*

Most of the commercial indicators have been tested at 18° and 90° in solutions of pure sodium hydroxide, and serious discrepancies are found in results with Sörensen's standard buffer solutions and with pure hydroxide, most of the indicators giving quite misleading and useless results. Two, or possibly three, indicators can be used in the presence of soaps, and under suitable conditions confirm measurements of the hydrolysis of soaps obtained by other methods.

(4) *The States of Matter exemplified by Soaps and their Solutions.*

Soaps form an almost unique material for the precise investigation of the relations between a number of interesting states of matter. Any one aqueous soap can be prepared in the form of true hexagonal crystal lamellæ: white, opaque (crystalline) curd fibres, transparent liquid crystals (conic anisotropic liquids), and transparent isotropic solutions which are dark when examined with crossed Nicols. The isotropic solutions are crystalloids or colloidal electrolytes, and the latter are either fluids or true jellies depending in a most regular manner upon temperature and concentration. A mass of quantitative data is now available for each of these states, and some insight has been obtained into their constitution and relationships.

(*b*) Prof. Wilder D. Bancroft.—*The Permeability of Membranes.*

(*c*) Prof. H. S. Taylor.—*The Adsorption from Silver Salt Solutions by Silver Iodide.*

(*d*) Dr. E. K. Rideal.—*The Chemical Union in Adsorption.*

(*e*) Prof. W. Lash Miller.—*The Distribution of Colloidal Gold between Two Liquid Phases.*

(*f*) Prof. E. F. Burton.—*The Mutual Action of Electrically Charged Particles in Solution.*

This paper deals with the mutual effect of particles in suspension in liquids due to their possession of an electrical charge.

Continuing experiments first performed many years ago by Dorn, Billiter, and Freundlich, small spheres of metal have been dropped through columns of various liquids and quantitative measurements made of the charges carried down by these spheres. It is observed that a scattering of the particles takes place which is undoubtedly influenced to a great extent by the charges borne by the particles.

(*g*) Mr. P. J. Moloney.—*The Absorption of Insulin by Charcoal.*

(*h*) Prof. Frank B. Kenrick.—*Traces of Colloids in Distilled Water.*

A discussion of the source and removal of motes in distilled water used for light-scattering measurements, and of the part these motes play in the prevention of the supersaturation of gases.

SECTION C.—GEOLOGY.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 465.)

Thursday, August 7.

1. *General Geology of the Toronto Region.*

(*a*) Prof. A. P. Coleman, F.R.S.—*The Pleistocene Rocks of the Toronto Region.*

Almost the whole surface of the Toronto region consists of Pleistocene drift materials, including a sheet of boulder clay resting on Ordovician shale, a series of interglacial beds 185 ft. thick, four more sheets of boulder clay with interstratified clay and sand, and shore cliffs and shallow-water deposits of Glacial Lake Iroquois.

The most interesting part of the drift is the Toronto Formation, of interglacial age, in which remains of nearly 200 species of plants and animals have been preserved, including numerous trees indicating a climate like that of Pennsylvania.

Good sections of the interglacial beds are to be seen in the Don Valley and at Scarboro' Heights, a few miles east on the shore of Lake Ontario.

The Toronto Formation is much the most extensive and important interglacial formation in America.

(*b*) Prof. W. A. Parks.—*The Palæozoic Strata at Toronto.*

The strata at Toronto belong to the Upper Ordovician. In the early days they were ascribed to the Hudson River Formation of the New York geologists; later they were referred to the Lorraine. As a matter of fact, the fauna is only in part Lorraine and with a strong admixture of western (Maysville) forms. It is proposed to give a local name to the formation at Toronto—Dundas formation.

While many fossils are common to the whole formation, it is possible on faunal grounds to divide it into four members—Rosedale, Davenport, Humber, and Credit.

Exposures are to be seen on the Don river east of the city and in a very large quarry in the valley of that stream; west of the city numerous exposures occur along the valley of the Humber river and in quarries still farther west.

A complete account of the stratigraphy and palæontology has been issued recently by the Ontario Department of Mines.

2. Prof. George D. Lauderback.—*Tectonic Geology of the Tsingling Shan, China.*

3. Dr. W. D. Matthew.—*A New Link in the Ancestry of the Horse.*

The series of American Tertiary ancestors of the horse is one of the classic examples of evolution provided by the fossil record, and the most complete and convincing among the mammals. Nevertheless it is well recognised by those who have made a special study of it that, while the broader lines of descent are beyond reasonable question, there are definite gaps between some of the successive stages, and many minor problems as to the details of phylogeny. It has been confidently believed that these gaps would be filled by the discovery of fossil Equidæ in the intervening strata heretofore barren, and from time to time such discoveries have been made and the predictions as to their character always more or less precisely verified.

The most serious gap that exists at present is between the Upper Eocene *Epihippus* and the Lower Oligocene *Mesohippus*, and this gap still remains. I anticipate that it will be at least partly filled by systematic search in certain western and northern outliers of the White River Oligocene, which contain an older fauna than the main exposures, but are very little known.

A second gap existed twenty years ago between *Miohippus* of the Upper Oligocene and *Merychippus* of the later Miocene, but this has been filled by the discovery in 1905-1916 of numerous species of *Parahippus* in the intervening Lower Miocene strata, so that it is now not easy to draw the lines of demarcation above and below *Parahippus*.

A third gap existed between the Lower Pliocene *Hipparion-Protohippus-Pliohippus* group and the Pleistocene and uppermost Pliocene *Equus*, the modern type of horse. The importance of this gap has been somewhat overestimated by some European authorities, whose estimate was probably based upon comparison of the European species of *Hipparion*, with the true *Equus*; it is, in fact, a rather small gap if comparisons be made with the various American species of these three genera. Some of these, however, were very incompletely known. The Middle Pliocene species referred to *Pliohippus*, from the Blanco formation of Texas and the Etchegoin of California, were intermediate in geological age, and in characters as far as known; but all that was known of them was a couple of teeth from the Blanco and three or four from the Etchegoin.

Mr. Childs Frick, who has been making a special study of the Equidæ, had urged upon me for some time the importance of further work in the Blanco formation, and provided the funds for such field work. This was taken up this spring with very satisfactory results. We were fortunate to secure, among other things, a nearly complete skeleton, lacking only the skull, and a second partial skeleton with well-preserved skull, of the large so-called *Pliohippus* from the Blanco. The first was found by myself, the second by my assistant, Mr. George Simpson.

It proves to be a very interesting type, intermediate between the typical *Pliohippus* of the Lower Pliocene and *Equus* of the Lower Pleistocene, so far as the characters were observed in the field.

It is of the size and limb-proportions of the smaller species of *Equus*, much larger and more robust than true *Pliohippus*. The teeth are most like *Pliohippus*, but longer-crowned and less curved, with heavier mesostyle and larger and more nearly isolated protocone. The skull has the elongate proportions of *Equus* in contrast to the shorter skull of typical *Pliohippus* and earlier Equids. It retains in the fore foot a tiny vestigial nodule representing the first digit, progressively reduced in the earlier stages of Equidæ, completely lost in *Equus*. The splints are little more than half the length of the cannon bone, nearly or quite as much reduced as in *Equus*, while in true *Pliohippus* the splints are almost as long as the cannon bone, and it is not certain that the lateral phalanges had entirely disappeared except in one unusually progressive species.

Many other characters will doubtless appear in the course of preparation and study of the two skeletons.

The intermediate character of the California species has been recognised by Dr. Merriam from the few teeth which he had to study. The discovery of

the entire skeleton now puts this stage completely on the map, and will enable us to trace in detail the transformation of every part of the skeleton. It remains, of course, to be seen whether our Blanco species is in all respects intermediate; it may prove to be a little off the direct line. But the genus that it represents is certainly the desired intermediate stage between *Pliohippus* and *Equus*, and may be known as *Plesippus*, a somewhat syncopated compound from πλήσιος, 'near,' ἵππος, 'horse.' The species is probably *P. simplicidens* Cope, described as a species of *Equus*, referred by Gidley in 1907 to *Pliohippus*. *Pliohippus proversus* Merriam is referred to the genus.

4. Dean G. F. KAY.—*Some Recent Interpretations of Glacial Deposits in Iowa.*

Iowa has long been recognised as being one of the most important areas of the world for the study and interpretation of glacial deposits of Pleistocene age. More than twenty years ago McGee, Chamberlin, Calvin, Leverett, and others found evidence, within the State, of deposits which were made during five glacial and four interglacial epochs.

In recent years some extensive field investigations have been made of the tills, gravels, gumbotils, fossils, and other materials of the glacial deposits. As a result of these studies some conclusions have been reached which differ from those of previous workers, and some new criteria have been found which it is hoped will aid in the interpretation of the complex history of the glacial period. Attention is called to the striking similarity in physical characters of the two oldest tills, to the origin of Aftonian gravels and their included faunas, and to the significance of gumbotil which had been developed on the three oldest tills. It will be shown that, on account of the distinctive characters of the gumbotils, their mode of origin, distribution, and topographic position, they are among the most satisfactory criteria that have yet been found for distinguishing the older drifts. Moreover, the gumbotils are discussed as factors in the interpretation of the relative durations of interglacial epochs.

5. Prof. W. A. PARKS.—*The Dinosaurs of Alberta.*

The Red Deer valley in Alberta is a deep gorge through Palæocene and Upper Cretaceous strata. Where the brackish-water Edmonton and Belly River formations are exposed great numbers of skeletons of dinosaurs are revealed, making the region one of the most prolific in the world as regards such remains.

More than twenty-five special expeditions have resulted in the collecting of at least 130 major specimens and a wealth of fragmentary material. The University of Toronto expeditions (1918-1923) have secured twelve to fifteen major specimens. Eight of these, some new to science, are mounted in the gallery of the Royal Ontario Museum.

6. Dr. F. A. BATHER, F.R.S.—*The Habits of some North American Cystids.*

That the evolutionary changes in animals are closely related to their habits and environment is a view that has of late lost ground in some quarters. It may, therefore, be worth while to show how the varied structures of some Ordovician cystids can be interpreted in terms of their mode of life. Forms familiar to Canadian hearers are chosen as the chief illustrations : *Syringocrinus* (=*Dendrocystis*), *Anomalocystis*, *Cheirocrinus*, *Pleurocystis*.

Afternoon Excursion to examine Palæozoic rocks near Toronto.

Friday, August 8.

7. Presidential Address by Prof. W. W. WATTS, F.R.S., on *Geology in the Service of Man.* (Page 88.)

8. Prof. E. S. MOORE.—*The Direction of Cleat in Coal.*

9. Prof. M. B. Baker.—*Metallogenesis and the Pre-Cambrian of Canada.*

Pre-Cambrian rocks occupy more than half the land area of Canada, and present a peneplained surface, developed during pre-Cambrian times. There were at least two great orogenic movements, developing mountain ranges not unlike the rocky ranges of Western Canada to-day. Both of these systems of mountains were eroded and base-levelled to a depth sufficient to expose enormous batholithic bodies of plutonic rocks.

The main topographic features of the country, the major courses of the streams, the longer axes of the lakes and main deflexions, the axes of the anticlinal and synclinal folds, and the general occurrence and shape of most of the intrusive bodies of igneous rocks, are all directly the result of the rock structure of the country, the general trend of all being in a north-easterly and south-westerly direction.

Formations that occupy so large an area, and that are so highly metamorphosed as to destroy most evidences of superposition, and all traces of fossil contents, will be open to many interpretations. There is a general agreement, however, that three great eras of time are represented, which may be referred to as the lower, middle, and upper pre-Cambrian, with two long periods of erosion that produced very great unconformities.

Each of the three eras was brought to a close by a period of marked igneous activity. It is noteworthy, however, that whereas the igneous intrusions that closed the upper pre-Cambrian era were accompanied by some of the greatest deposits of copper, nickel, silver, cobalt, and iron that the world has known, and that similarly some of the richest gold deposits yet found accompanied the igneous activity that closed the middle pre-Cambrian era, the igneous rocks that mark the close of the lower pre-Cambrian era show no evidence of metalliferous content, at least of economic value.

As the igneous rocks of all three periods cut through country rocks of both sedimentary and igneous origin, and which vary in all degrees of basicity, it is evident that these marked differences in ore deposition cannot be due to the country rocks, but must be explained by the character of the intrusions themselves. The intrusions that closed the middle and the upper pre-Cambrian eras show striking evidences of differentiation, the well-known Sudbury batholith being the world's classic example of this process. The igneous rocks reported as closing the lower pre-Cambrian era show no evidence of differentiation. They are described as grey to pinkish granite (gneisses).

Since differentiation of rock magmas, the development of sub-magmas, and the expulsion of mineralisers during the crystallisation of igneous rocks, are looked upon as the controlling influences in ore-deposition, it would appear that the economic future of the pre-Cambrian areas of Canada depends on the general delimitation of those highly differentiated igneous rocks that mark the close of the middle and upper pre-Cambrian, followed by an intensive and careful exploration of their contacts with suitable country rocks.

10. Assoc.-Prof. Alexander MacLean. — *The Structural Features of the Kirkland Lake Gold District.*

11. Dr. J. M. Bell and Asst.-Prof. Ellis Thompson.—*The Effect of Deep-seated Alterations upon the Mineralogical and Geological Features of the Keeley Mine.*

The Keeley Mine is situated in the district of South Lorrain, about sixteen miles south-east of Cobalt. The Keeley, both in the nature of its general geology and in the details of its vein-structure, is very similar to Cobalt, but it is noteworthy at the Keeley that the veins occupy pronounced faults, while those of Cobalt are ordinarily in joint-like cracks, in which there has been little or no displacement. The most interesting differentiation, however, is to be found in the extent to which weathering is effective at the Keeley, as compared with Cobalt proper. This unusual alteration at the Keeley is associated with a zone of pronounced and radiating faulting, which is believed to have connection with the major faults of the district. The latter are occupied by such

basins as Lake Timiskaming, the Montreal River, and Trout Lake. The pronounced alteration, which has now been traced downwards in the Keeley workings to a depth of 600 ft., is limited to the southern part of the mine workings, where various minor pre-mineralisation faults join the main fault occupied by Woods' vein. The alteration may be described as a pre-glacial 'fossil,' having been protected from glacial erosion by the narrowness of the southern portion of the valley, which forms the surface expression of Woods' vein. In other words, in this section the glacier seems to have been forced locally by topographical conditions to deposit rather than erode.

MINERALOGICAL SUMMARY.

Unaltered Material.	No. 3	No. 8	No. 9	Average
Cobaltite..................CoAsS	8·13	11·48	2·32	7·31
Lœllingite ....$FoAs_2$	63·35	37·37	22·42	41·05
Rammelsbergite ....$NiAs_2$	—	—	20·50	6·83
Safflorite....................$CoAs_2$	24·45	10·87	5·22	13·51
Skutterudite ....$CoAs_3$	3·52	40·90	49·10	31·17
	99·45	100·62	99·56	99·87

The metallic minerals present in the analysed samples from the unaltered portions of the mine include lœllingite, skutterudite, safflorite, cobaltite, and rammelsbergite, in that order of prevalence. It will be noted that lœllingite and skutterudite are the most constant constituents, while the safflorite and rammelsbergite vary in quantity, and cobaltite is a minor constituent, seldom exceeding 10 per cent. of the section.

Altered Material.	No. 1	No. 6	No. 6B	No. 7	Average
Cobaltite ....CoAsS	4·82	4·98	3·44	30·2	10·43
Gersdorffite ......NiAsS	—	—	—	39·4	10·28
Lœllingite.........$FoAs_2$	13·89	82·0	13·09	17·92	42·30
Skutterudite......$CoAs_3$	38·16	—	80·57	11·93	32·67
Chloanthite ......$NiAs_2$	35·06	—	—	—	8·77
Smaltite ....$CoAs_2$	7·94	11·10	1·05	—	5·02
Tetrahedrite ...$Cu_3Sb_2S_7$	0·84	—	—	—	0·21

The metallic minerals in the analysed samples from the partially altered parts of the Keeley include lœllingite, skutterudite, cobaltite, gersdorffite, chloanthite, smaltite, and tetrahedrite, in that order of prevalence. The first three named are the most constant in quantity, with the remainder in minor and varying amounts.

A comparison of these two tables shows that the three constituents, lœllingite, skutterudite, and cobaltite, are the most constant both in the unaltered and the partially altered material. They appear to be the least susceptible of the metallics and might be expected to survive the alteration processes to a very large extent. The rhombic diarsenides, on the other hand, which are prevalent in the unaltered material, disappear entirely in the altered portions, being replaced by the corresponding cubic representatives. This significant feature may be accidental or may be the result of a radical change in the molecular structure of these constituents. In any case, the order of susceptibility to alteration of the mineral constituents would appear to be: rammelsbergite, safflorite, chloanthite, smaltite, lœllingite, skutterudite, and cobaltite.

It is believed that the alteration has resulted in considerable elemental migration, a marked change in the mineralogical character of the altered vein material as compared with the unaltered, and a considerable enrichment in silver values towards the bottom or actually beneath the altered zone.

12. Dr. L. J. SPENCER, F.R.S.—*International Agreement in Mineralogical and Crystallographical Nomenclature.*

Afternoon Excursion to study the Glacial Phenomena in the Toronto Region.

Saturday, August 9.

Excursion to the Niagara-Grimsby district.

Monday, August 11.

13. Joint Discussion with Section E on *Changes of Sea-level in Relation to Glaciation, Continental Shelves and Coral Islands.*

(*a*) Prof. REGINALD A. DALY.—*Delevelings connected with Glaciation and Deglaciation.*

Charles Maclaren, in 1842, appears to have been the first to see the importance of world-wide shifts of sea-level, due to the abstraction of water from the ocean to form the Pleistocene ice-caps. Other estimates of the maximum eustatic shift of this kind have been made by Croll, Tylor, Belt, Upham, Penck, Drygalski, Nansen, Daly, W. B. Wright, Humphreys, W. Ramsay and others. The values run between 40 metres and about 900 metres. The most probable value is of the order of 50 metres; that for the last important deglaciation (Wisconsin, Würm) may be taken as about 40 metres. The changes of the ocean's volume entailed elastic, and perhaps isostatic, deformations of the whole earth; in consequence the range of the displacements of the strand-line on continental shores must have been less than the range registered on the deep-sea islands.

Calculations, founded on the work of Rudzki, R. S. Woodward, Chree, G. H. Darwin and others, show that the deformation of the geoid by glaciation or deglaciation was too slight to be of practical significance in the strand-line problems of the Pleistocene period.

The isostatic adjustments connected with glaciation and deglaciation and causing crustal warps seem to have been dominated by the flow of the earth's materials at great depth. If so, another important part of each crustal warping was an elastic reaction. Further, considerable elastic distortion of the whole earth must have occurred during the long periods of delay in the establishment of isostatic equilibrium which was disturbed by the formation and disappearance of the ice-caps. The 'marginal bulges' around the ice-caps were caused chiefly by such elastic reactions. The collapse of these 'bulges' during the restoration of isostatic equilibrium seems competent to explain the drowning of British forests and some other phases of submergence in the belt peripheral to the area of heavy glaciation in Fenno-Scandia.

The principle of the eustatic shifts of sea-level is illustrated in a post-Glacial, six-metre lowering of sea-level, world-wide in its effects. New evidence of this general change of sea-level has been found at Saint Helena, the Cape of Good Hope, South-west Africa, West Africa, Bermuda, South Australia, New Zealand, Hawaii, etc.—localities additional to those listed in the *Geological Magazine* (1920).

The relation of the last, positive, eustatic shift of sea-level to the location (drowning) of shore sites and delta sites of Palæolithic man is briefly discussed. The same rise of sea-level explains the forms and relations of the *living* coral reefs, the development of which seems to be independent of the local subsidence of the sea-floor exemplified in Fiji and other parts of the south-western Pacific. Emphasis is laid on the excessive muddiness of the sea-shores during the glacial stages and the consequent inhibition of vigorous reef-growth at those times. Such 'mud-control' may then have been even more important than temperature-control over the growth of the reef corals. The formation of numerous atolls and barrier reefs has been conditioned by the special *clearness* of the water on shelves and banks, the surfaces of which had been washed and lowered (de-graded) at the lower sea-levels of the glacial stages. There is no evidence that many atolls and barrier reefs ever existed in pre-Glacial time.

(*b*) Prof. W. M. DAVIS.—*Modification of Darwin's Theory of Coral Reefs by the Glacial-control Theory.*

An examination of a number of reef-encircled islands in the Pacific and a study of all theories of coral reefs has led to the conclusion that Darwin's theory of upgrowing reefs on intermittently subsiding foundations should be modified by

adding the effects of Glacial changes of ocean level and temperature, but that the modifications thus introduced do not greatly affect the original theory.

Upgrowth over subsiding foundations still appears to have been the determining factor in all barrier and atoll reefs of discoverable origin; the effects of Glacial changes of ocean level and temperature appear to be of subordinate value as compared to the effects of long-continued subsidence. Inhibition of reef growth by reduction of ocean temperature in the Glacial epochs, with a resulting low-level abrasion of pre-existent reefs and a cliffing of the islands behind them, appears to have taken place in a marginal belt of the Pacific coral seas between latitudes 23° and 28° N. and S.; but in the coral seas proper reef growth does not appear to have been thus interrupted. Although changes of ocean level are believed to have taken place in the Glacial Period, it has not been possible to determine their amount by their effects.

(c) Prof. A. P. Coleman, F.R.S.—*Raised Beaches as Related to the Thickness of Ice Sheets.*

Raised beaches occur in eastern, northern, and western Canada, and the amount of elevation of such beaches above sea-level appears to be roughly proportional to the thickness of ice removed at the end of the Glacial Period, thus supporting the theory of isostatic equilibrium.

Instances are given showing these relations in Ontario, Quebec, the Maritime Provinces, Newfoundland and Labrador.

General Discussion.

14. Prof. W. M. Davis.—*An Uptilted and Bevelled-off Atoll.*

If an atoll, thirty miles in diameter, were uptilted by deformational forces so that about half its area were raised above sea-level with a slant of 15°, and then bevelled off by degradational processes, its understructure would be well revealed. If the atoll had been built up over a subsiding foundation according to Darwin's theory, the revealed understructure should exhibit a rock series of a considerable thickness, including volcanic rocks of subaerial eruption at the base, and marine calcareous beds above; the latter should contain corals and other fossils indicative of deposition in shallow water. An island of this kind will be described, in which the thickness of the bevelled-rock series is about five times the depth of the Funafuti boring.

15. Prof. J. W. Russell.—*Evidences of a quite recent Extinction of the American Mastodon.*

(1) Most Mastodon remains have been recovered from post-glacial bogs containing either peaty material or marl, which acted as a preservative, thus obscuring the time interval.

(2) During the past two years three places containing Mastodon skeletons were visited; one of these had neither marl nor peat as a preservative.

(3) Description and views of this location and samples of the bones found will be given; also description of the rapid weathering and dissolving that would have occurred here.

16. Mr. Leverett.—*Glacial Phenomena in Kentucky.*

17. Mr. L. D. Huntoon.—*Gold Production in Canada.*

18. Dr. H. M. Ami.—*Palæozoic Problems in Eastern Canada.*

19. Mr. C. F. Kelly.—*Mineral Detection by means of its Electrical Activity*

20. Mr. W. L. T. Addison.—*A Molecular Form of Calcium Carbonate accounting for the Crystal Forms of Aragonite and Calcite.*

Any form assumed for a molecule should, to be tenable, account for the crystal form or forms in which the compound occurs.

The concept of the carbon atom arrived at by the stereo-chemist is that of a regular tetrahedron. This form also accounts for the crystal forms of carbon. The carbon or central atom in calcium carbonate would have its space occupation extended in one dimension by one oxygen atom and at right angles in a second dimension by two oxygen and one calcium atoms. The third dimension would arise from the added dimensions of the atom and group of atoms on either side of the carbon atom. The space occupation of such a group is roughly that of a tetrahedron.

The tetrahedron which may be deduced for Aragonite would be an orthorhombic one of dimensions X 6.7157 : 4.1822 : 2.4188 (the molecular volume of calcium carbonate being 33.678 in Aragonite). The angle over the short edge is 108, 26, 24, a little less than 120 degrees. This angle apparently lends itself to the formation of a triad group of molecules which in turn gives rise to a rhombohedral grouping approximating closely in axes and specific gravity Calcite.

Tuesday, August 12.

Morning.

21a. Joint Discussion with Section B (*q.v.*) on *Liquid and Powdered Fuels.* (Page 377.)

21b. Discussion on *The Pre-Cambrian Rocks of the World.*

(*a*) Dr. W. G. Miller.—*The Pre-Cambrian Rocks of Canada.*

As the years go on the pre-Cambrian is of increasing interest, both from the scientific and the economic point of view. The relationships of the rocks are gradually being unravelled on various continents, and mineral production is becoming more widespread. While the oldest pre-Cambrian of most of the continents has certain striking characteristics in common, especially the occurrence of the peculiar iron formation known as jaspilite, the time has not arrived for attempting, with a degree of confidence, the correlation of these most ancient rocks of one continent with those of others. All that can be said at present is that the resemblance in succession in certain cases is remarkable.

In the Provinces of Ontario and Quebec, where the pre-Cambrian was first studied systematically, and where the rocks were divided into two groups, the lower or Laurentian and the upper or Huronian, later work has shown it to be more complex than it was believed to be. It was in 1845, during a trip to Lake Timiskaming, that W. E. Logan first saw the conglomerate and other sediments to which he afterwards gave the name 'Huronian,' owing to their occurring in large volume on the shore of Lake Huron. On this trip to Timiskaming he also noted the unconformable relationship of the conglomerate to granite and gneiss which came to be known as the Laurentian. More recent work has shown that in Northern Ontario there are granites of at least three ages, separated by great intervals of time, and the term Laurentian is now applied to the oldest. There are also older series of sediments than those that Logan saw lying unconformably on the granite of Timiskaming. The following table brings out the relationships of the rocks that are now known to occur in the Cobalt-Lake Timiskaming area. It also shows that what is now known as the Cobalt series corresponds to Logan's Huronian sediments, and the Algoman to his Laurentian.

EOZOIC OR PRE-CAMBRIAN

	Present Classification of pre-Cambrian Rocks at Cobalt and Lake Timiskaming.	*Logan's Classification of 1857, based on visit to Lake Timiskaming in 1845, and later to Lake Huron.*
Upper	KEWEENAWAN Nipissing diabase, &c. ANIMIKEAN Cobalt series—conglomerate, &c.	Huronian Conglomerate, &c.
	GREAT UNCONFORMITY	
Middle	MATACHEWAN Diabase, &c. ALGOMAN Lorrain granite. HAILEYBURIAN Lamprophyre, diabase, &c. TIMISKAMIAN Conglomerate, &c.	Laurentian Granite, gneiss.
	GREAT UNCONFORMITY	
Lower	LAURENTIAN Represented by granite pebbles in Timiskamian conglomerate. LOGANIAN Grenville — iron formation, &c., in minor quantity, elsewhere much crystalline limestone, &c. Keewatin—Basic lavas, &c.	

While the Keweenawan in this area is represented only by diabase and related rocks, in the Sudbury area and along part of the shore of Lake Huron there are large intrusions of granite of this age, and around the shores of Lake Superior Keweenawan igneous and sedimentary rocks occur in great volume.

Beneath the Keweenawan and above the Algoman in Ontario there are series of sediments to which the name Animikean is given in the table. These series have not been satisfactorily correlated with one another. Unconformities are known, but they are not of the magnitude of that at the base of the Cobalt series or of that between the Timiskaming series and the older rocks.

The relationships of the Timiskaming series have been worked out over a large territory, and it appears to occur, in more or less isolated areas, across all the northern part of Ontario, and extends into Quebec on the east and apparently into Manitoba on the west.

The Keewatin, with iron formation, is found over a large region across Ontario and to the east and west. The Grenville series occurs in greatest volume in south-eastern Ontario.

The name 'Huronian' is not used in the table, as it has been applied indiscriminately to what are now known as the Cobalt series, the Timiskaming series, and the Keewatin. Even at present it is employed in different senses by various authors, and some of the so-called Lower and Middle Huronian may be Timiskamian.

(*b*) Dr. J. S. FLETT, F.R.S.—*The Pre-Cambrian Rocks of Britain.*

(*c*) Sir THOMAS HOLLAND, F.R.S.—*The Pre-Cambrian Rocks of India.*

It is assumed that sedimentary systems like the Cuddapahs (Gwaliors) and Vindhyans are unfossiliferous because of their probably pre-Cambrian age

They are comparable to the Animikies and Keweenawans of Canada in position and general features, but there is independently indirect evidence of their being older than Carboniferous.

With these are considered the highly folded and foliated basement complex, which is separated by a great erosion interval, assumed to correspond to Lawson's Eparchæan interval and the interval between the Algomans and the Cobalt series in north-east Ontario.

As the whole pre-Cambrian has now been worked out more satisfactorily in Ontario than in any other part of the world, the classification adopted there is taken as a guide in the attempt to find analogies among the old formations in India. The possibility of a general correspondence between the great 'breaks' is thus recognised as a preliminary working guide, qualified by the probability, almost certainty, that correspondences even of the partial exactitude accepted among fossiliferous formations do not occur.

With this working hypothesis in view, the assumption that the Dharwars in India are our oldest sediments merits reconsideration. The doubtful nature of this assumption was indicated in 1913 (*Compte-Rendu, Congrès Géologique Internat.*, 378), and in the absence of continuous mapping, deformed eruptives—granites, anorthosites, nepheline-syenites, &c.—associated with the basement complex were referred to as petrographical provinces Archæan in age, but of unknown relations in age to one another and to the Dharwars as a whole.

Unconformities of a major kind like that now recognised as separating the Laurentian and Timiskamian in Ontario were also indicated in 1913 as occurring in the basement complex of India. Recent work in Canada will enable workers in India to examine more critically the formations grouped together as Dharwar because of their general lithological resemblances. Some possibly correspond with the Timiskamian and others with the immensely older Loganian schists.

Reasons are given in this paper for confirming the dual group correlation adopted in 1913. It is urged that the interval between the Dharwars and the Gwaliors in India and that between the Timiskamian-Algoman and the Cobalt-Sudbury series in Canada should be recognised still as a main group boundary of greater practical importance than that between the Loganian and Timiskamian.

The additional modification of the term Archæan, which has followed recent work in Canada, suggests the adoption of new group names, one for the pre-Cambrian above the Timiskamian, and one for the enormously larger group of foliated rocks below.

(*d*) Dr. M. E. Wilson.—*The Grenville Pre-Cambrian Subprovince.*[1]

By far the greater part of our information regarding the geology of the Canadian Pre-Cambrian shield has been obtained in the territory lying along its southern border and chiefly in four districts or subprovinces : (1) the region north-west of Lake Superior; (2) the region south of Lake Superior in United States; (3) the region extending north-east from Lake Superior and Lake Huron to Lake Timiskaming and Lake Huron—Timiskaming Subprovince—and (4) south-eastern Ontario, the southern Laurentian highlands of Quebec and the Adirondack region, which together form the Grenville subprovince. These districts are geographically and geologically separate from one another, for between the Grenville and Timiskaming subprovinces there intervenes a belt of banded gneisses, between the Timiskaming subprovince and the western subprovinces there is the wooded Pre-Cambrian highlands, largely underlain by granite and granite gneiss on the north and the overlapping Palæozoic sediments on the south, and between the north-western and south-western subprovinces lies Lake Superior.

The purpose of this paper is (1) to outline briefly the geology of the most easterly of these subdivisions—the Grenville subprovince—and (2) to indicate the most probable relationships of the formations of the Grenville subprovince to those of other parts of the Canadian shield and more particularly to those of

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the Timiskaming region, to which, because of their proximity, they are probably most closely related.

The formations of the Grenville subprovince in Ontario and Quebec, except for the unconsolidated Pleistocene and recent deposits and a few intrusions of lamprophyre, diabase, granite, and syenite, of late Pre-Cambrian age, all belong to a typical basal complex. This constitutes the Laurentian of Logan, and because of its highly metamorphosed condition has always been regarded as early Pre-Cambrian in age. The formations are in some respects the same throughout the whole region, but certain differences exist between its western and eastern parts, as shown in the following tabular statement of the succession of formations in each.

	WESTERN PART (South-Eastern Ontario)	EASTERN PART (Quebec)
LATE PRE-CAMBRIAN		Grenville and Rigaud stocks of granite and syenite
	Diabase dykes	Diabase dykes
		Lamprophyre mass and dykes
EARLY PRE-CAMBRIAN (Laurentian of Logan)	Batholithic intrusives: Granite, granite gneiss, and pegmatite. Syenite, and syenite gneiss	Batholithic intrusives: Granite, granite gneiss, and pegmatite. Syenite, and syenite gneiss
	Gabbro and diorite	Buckingham series (igneous): Pegmatite, shonkinite, pyroxene diorite, norite, anorthosite, peridotite, &c.
	Hastings series: Limestone, dolomite, argillite, greywacke, and conglomerate	
	Grenville series: Crystalline limestone, dolomite, quartzite, mica schist, sillimanite-garnet gneiss, and lava flows	Grenville series: Crystalline limestone, sillimanite-garnet gneiss, and quartzite

The formations occurring in the Grenville and Timiskaming belts are, for the most part, lithologically unlike, so that in attempting their correlation several hypotheses must be considered. Of these the most important are the following: (1) that the Hastings or Hastings and Grenville series are entirely or in part equivalent in age to the Huronian, a possibility suggested to the writer several years ago by W. H. Collins and recently advocated by Quirke; (2) that the batholithic intrusions of granite and granite gneiss occurring in the two regions are of the same or about the same age; (3) that the Grenville series is of about the same age as the Abitibi (Keewatin of some writers) group; (4) that the Hastings series is correlative with the belts of sediments classed as Timiskaming in the Timiskaming belt; and (5) that the Grenville or Grenville and Hastings series are older in age than the Keewatin group.

Evidence for and against these possibilities is presented.

(*e*) Prof. T. T. Quirke.—*Correlation of the Huronian and Grenville Rocks of South-Eastern Ontario.*

Current hypotheses of correlation are applied to the north shore district of Lake Huron. Lawson's classification, based on the times of Laurentian and Algoman granites, does not apply. The younger granite in this area is of so-called Keweenawan age, known by the local name Killarnean.

H. C. Cooke has traced Grenville sedimentary schists across granite batholiths into the Nemenjish series of north-western Quebec; he concludes both are very much older than the Huronian series. In south-eastern Ontario Grenville rocks are not older than the Huronian series.

Recent discoveries near Killarney indicate that the Huronian series are identical with certain contact metamorphosed sediments previously called Grenville, and that many other occurrences of sedimentary schists and intruding granite, now mapped as Grenville and Laurentian, will be shown to be Huronian and Killarnean. The evidences described concern: (1) Huronian sediments included within granite gneisses between the Huronian areas and Grenville areas; (2) the persistence of the structure characteristic of the Huronian terrane into the region of Laurentian and Grenville rocks; (3) the fact that Keweenawan quartz diabase near Killarney is contact metamorphosed into amphibolites similar to those described in the Haliburton-Bancroft area, and the fact that in nearly all the north-eastern Pre-Cambrian regions not intruded by Killarnean granite, there are quartz diabase or similar dykes, whereas there are none recognised in the Grenville areas. This implies that such Grenville rocks are intruded by a granite younger than Keweenawan diabases and probably the same in age as that at Killarney.

(*g*) Prof. R. C. Wallace.—*Some Types of Mineralization in the Pre-Cambrian Rocks.*

(*h*) Dr. Ellsworth.—*Radioactive Minerals as Age Indicators in Geology.*

A critical discussion of the method of measuring geological time by atomic disintegration. Many problems are involved, including apparent lack of concordance of certain results. The importance of exact chemical analyses. Owing to the limitations of analytical methods at present, non-concordance of results may be due to experimental errors in some cases. Radioactive minerals probably are of much more common occurrence than is generally supposed. The relative values of such minerals as age indicators depend on their chemical composition, quantities obtainable, and frequency of occurrence. Possibilities of concentration from rocks. Recent Canadian work. Canadian radioactive mineral occurrences afford favourable conditions for testing the reliability of the method.

(*i*) Prof. A. P. Coleman, F.R.S.—*Pre-Cambrian Climates.*

The belief once current among geologists that the earliest Pre-Cambrian rocks represented the original crust of the earth, formed as it cooled from a molten to a solid condition, has long ago been given up, and evidence is growing that climates and geological processes in those early times were not widely different from those of later times.

Passing downwards from the base of the Cambrian in Canada the Keweenawan includes red sandstones suggesting desert conditions; the Animikie, with grey carbonaceous slates, was probably a time of cool, moist climate; and the Huronian, including the Cobalt tillite, was a time of glaciation.

Below this, after a profound break, is the Sudbury or Timiskaming series, mostly of water-deposited materials, including 4,000 ft. of well-banded graywacke and slate, evidently of seasonal origin. This gritty but well-stratified material and some boulder conglomerates make one suspect a cold and perhaps glacial climate.

After another great unconformity the Keewatin and Grenville series, with carbonaceous slate and thick beds of limestone, suggest conditions not very different from the present. The thousands of feet of boulder conglomerate in the Doré series are thought by some to be torrential deposits, but might equally well be accounted for as glacial.

On the whole, the Pre-Cambrian formations indicate cooler conditions than the Palæozoic up to the end of the Carboniferous, and much cooler conditions than those of the Mesozoic.

Wednesday, August 13.

22. Mr. Edward M. Kindle.—*Certain Types of Sedimentation now in Progress on or near the Atlantic Coast of North America.*

Certain phases of sedimentation on the Labrador coast, the Bay of Fundy, the south-east coast of Florida, and the Bahama islands are briefly described. These include the current-formed terraces of Lake Melville, Labrador, and other features relating to the inland and sea coast sediments of Labrador, the deposits of the inter-tidal zone of the Bay of Fundy, the Coquina beds of St. Augustine, Florida, and the æolian limestone of Providence Island in the Bahamas. Examples of lithification of calcareous deposits now in progress in the Florida-Bahama region are described.

23. Dr. C. A. Matley.—*Recent Geological Work in Jamaica.*

The paper gives a preliminary account of the scientific results obtained in the course of geological investigations of an economic character, chiefly in connection with water-supply, in various parts of Jamaica. The author was assisted in the later stages of the work by Mr. G. M. Stockley, A.R.C.S., A.I.C., F.G.S., and he is indebted to Dr. T. W. Vaughan and Dr. W. P. Woodring, of the U.S. Geological Survey, for the examination of some of the foraminifera and mollusca of the White Limestone.

The field work confirms in its main outlines the mapping of the formations by Sawkins and his colleagues as shown on their map of 1865, with the exception of the unfortunate mistake, afterwards corrected by Prof. Hill, of correlating with the Yellow Limestone certain strata in the east of the island which are newer than the White Limestone. Several other corrections introduced by Hill in his revision of Sawkins's map (1899) are, however, not accepted. The strata are capable of greater subdivision than has been previously recognised or attempted, the subdivisions of the older rocks being chiefly lithological, and of the newer rocks chiefly palæontological.

The *Metamorphosed Series* of Sawkins, as Hill has pointed out, is not a stratigraphical series. In the mountainous country to the north-east of Kingston it is a folded complex of rocks, of which the dominant member is a great mass, apparently not less than 1,000 feet thick, of pale buff or grey porphyry, with phenocrysts of hornblende and felspar and sometimes of quartz, which was intruded as a laccolite or sill before, or at an early stage of, the folding. It has already been traced over a belt of country, with a N.W.-S.E. trend, fifteen miles long by five miles wide. Its platy or flaggy structure caused Sawkins to regard it as an altered sandstone. The associated rocks belong mostly to Sawkins's Conglomerate Group, and are composed mainly of epiclastic igneous material, but they also contain some calcareous flags and a thick limestone (Good Hope or Halberstadt Limestone). An interesting volcanic episode has been discovered in the strata below the Good Hope limestone, where there are two or more flows of highly vesicular pillow-lava and some tuffs. The outcrops of the lavas have been found brought up by folding over an area nine miles in length. Also associated with the purple conglomerate group are gypseous beds. The gypsum was considered by Sawkins to be of secondary origin, and to have been formed by the action of sulphuric acid on the local limestones. But the discovery of pseudomorphs of rock-salt crystals among these deposits and the presence of salt springs indicate that the gypsum and rock-salt were precipitated by concentration of the water of a salt lake or marine lagoon. These minerals and their association with unfossiliferous purple and red rocks remind one of the Triassic rocks of England, and suggest that somewhat similar conditions once existed in Jamaica. The age of these deposits is probably early Eocene, though possibly Cretaceous.

Hitherto no rocks earlier than Cretaceous have been recognised in Jamaica

except as pebbles in Cretaceous and Tertiary strata. Hornblendic granite or diorite has, however, been found to underlie conglomerates made up largely of its débris, the conglomerates being certainly not newer than early Eocene; this plutonic rock probably formed part of the Cretaceous floor. Good crystalline schists (hornblende-schists and quartz-sericite-schists) and marble have also been found among unaltered strata in the basin of the River Yallahs. These and the serpentines which occur in the same area all appear to be of pre-Mesozoic age, like the similar rocks in Cuba, but their field relations have not been fully studied.

An effort has been made to zone the Tertiary limestones by means of their foraminifera. The Yellow Limestone, recently proved by Trechmann to be of Middle Eocene age, contains beds full of *Operculina* with a few minute *Dictyoconi*, occasional beds of *Alveolina*, and others of a large *Orthophragmina*. The overlying White Limestone ranges from Upper Eocene to Upper Oligocene, the foraminiferal succession in ascending order being as follows: *Alveolina* and *Dictyoconus*; *Dictyoconus* without *Alveolina*; small lenticular Lepidocyclines; large Lepidocyclines (zone of *Lepidocyclina* cf. *gigas* and *L. undosa*); *Sorites*. The *Sorites*-zone forms the Santa Cruz Mountains of St. Elizabeth and large tracts of Manchester. The flint-bearing, chalky, and globigerinal 'Montpelier Formation' of Hill lies below the *Lepidocyclina undosa* zone, but its type of sedimentation is missing from the succession in many parts of the island, and it seems to be a deep-water facies of the White Limestone that passes laterally into shallower-water mollusca-bearing beds. Hill's 'Moneague Formation' certainly includes the *L. undosa* zone, but its upper limit was not defined by that writer. Above the Moneague Formation he placed his 'Cobre Formation' as the highest division of the White Limestone, but the type section in the Cobre gorge contains an abundance of *Dictyoconus* and an absence of *Sorites* in the lower part of the gorge, an indication that the strata lie below the *L. undosa* zone and below the Moneague beds. The base of the White Limestone is of variable horizon, sometimes passing up conformably from the Yellow Limestone, sometimes overlapping on to older rocks against the shores of a subsiding land.

An account is given of the igneous rocks. The latest intrusions appear to be of Upper Eocene age. The Low Layton 'Extinct Volcano,' possibly of Oligocene age, was found to contain many 'pillows' of highly vesicular lava, the pillows being sometimes truncated, and the vesicles being usually arranged inside the pillows in well-defined concentric zones.

24. Dr. C. A. Matley.—*A Reconnaissance Geological Survey of the Cayman Islands, British West Indies.*

The Cayman Islands, a dependency of Jamaica, consist of the two smaller islands of Cayman Brac and Little Cayman and a larger island, about sixty miles from the Lesser Caymans, known as Grand Cayman. They are the only projecting peaks of the submarine Cayman Ridge that extend from the Sierra Maestra range of Cuba to the Misteriosa Bank in the direction of British Honduras. Cayman Brac rises to 130 or 140 feet above the sea at its eastern end, but the other islands do not exceed 50 or 60 feet. The submarine slopes round the individual islands are steep. Within eighteen miles of the shores of Grand Cayman a depth of over 20,000 feet is attained (Bartlett Deep).

The geology of the group has hitherto been practically unknown. The present survey has shown that each island contains limestones of two different ages, an older limestone (*Bluff Limestone*) closely resembling the white limestone of Jamaica, and forming an inner and more elevated platform, and a younger calcareous formation (*Ironshore Limestone*) forming an outer and lower coastal platform, the seaward edge of which is covered in many parts by modern shore deposits of coral-sand and coral-shingle thrown up by winds, storms, and hurricanes. Out at sea are coral reefs that surround the islands of Grand Cayman and Little Cayman almost completely, and occur to a lesser extent around Cayman Brac.

The *Bluff Limestone* is a massive white recrystallised limestone, with its fossils so poorly preserved as casts that usually they cannot be determined specifically. Among them occur mollusca (chiefly gasteropods), reef-building corals, nullipores and foraminifera. At the Bluff of Cayman Brac is a bed full of large Lepidocyclines which have a close resemblance to those of the zone of *Lepidocyclina gigas* and *L. undosa* found in the middle beds of the white limestone of Jamaica, and occurring

also in Antigua, Mexico, and other parts of the Caribbean area. The Bluff Limestone of Cayman Brac is therefore regarded as of Middle Oligocene age, while that of the other Cayman Islands seems, from the few identifiable fossils collected, to be of somewhat later age, probably Miocene. Terrigenous material is absent from this limestone, and deposition in a clear sea of no great depth is indicated.

The *Ironshore Formation* of consolidated coral-sand, marl and limestone represents the latest accretion to the area of the islands by a change in the relative level of sea and land. It forms a low rocky shore, known locally as 'ironshore,' and rises inland to a height of 12 to 15 feet above the sea, where it is generally backed by raised marine cliffs of the Bluff Limestone, which retain their verticality and freshness and show undercutting at their base by ancient wave-action. This coastal formation contains many well-preserved reef-building corals and numerous mollusca like those living round the islands at the present day. It is of Recent, or possibly of Pleistocene, age. A similar terrace, at about the same elevation, similarly backed by vertical cliffs of White Limestone, occurs on the north coast of Jamaica.

Residual brown and red earths have been formed from the limestones of both ages, as in Jamaica, by the solution of their carbonate of lime. Deposits of phosphatised earth and limestone occur sporadically, and presumably were produced by the contamination of the rocks by the excreta of sea-birds. They are no longer worked commercially.

The Cayman Islands may have existed as islands since Miocene times. The character and fauna of the Bluff Limestone show that we have in the three islands three fragments of the thick and widespread White Limestone formation that extends over more than half of Jamaica on the south-east and over large areas in Cuba on the north, though now separated from both those countries by profound depressions of the sea floor. As the Bluff Limestone was deposited in a sea of moderate depth, and as the highest point in the Caymans is only 140 feet above sea-level, the elevation necessary to form the islands was of modest dimensions when compared with the great depressions north and south of the Cayman Ridge. The elevatory forces seem to have acted almost vertically, as no folding has been observed, but there is a slight axial tilt in Cayman Brac. Aerial denudation has had time since elevation took place to convert the surface of this upper platform into a matured 'karst' country, now thickly forested. The latest important change of level was that which added the coastal platform to the islands in Recent or Pleistocene times. As similar low terraces are found in Jamaica, Cuba, and other parts of the Caribbean region, the change of level seems to have been widespread, involving more than one tectonic unit, and may therefore have been due more to a fall in sea-level than to earth movement. Around the shores a shallow submarine platform extends about as far as the 10-fathom contour, beyond which the depth increases rapidly, and on this platform the modern coral reefs grow.

The author has received palæontological assistance from Dr. T. W. Vaughan.

25. Prof. O. T. Jones.—*The Ordovician-Silurian Boundary in Britain and North America.*

Owing to various causes American geologists find difficulty in correlating the rocks near the Ordovician-Silurian boundary with the divisions established in Britain. Some of these difficulties are due to early stratigraphical errors, others may be ascribed to imperfect descriptions of British Palæozoic faunas, and others are due to differences between the facies of the American and British rocks. The author classifies the Upper Ordovician and Silurian rocks into three facies—pelitic, psammitic, and calcitic—according to their situation relative to the shore lines of the periods, and on the basis of the distribution of brachiopod and trilobite genera attempts a correlation of North American divisions with British rocks.

As regards Anticosti, the author is in agreement with Twenhofel in correlating the English Head, Charleton and Ellis Bay formations with the upper part of the Bala and the Becsie River, Gun River, Jupiter River, and Chicotte formations with the Silurian. These are mainly equivalent to the Upper Llandovery, but the Lower Llandovery appears to be poorly represented by the Becsie River formation.

On the American continent the Richmond formation is claimed to be Ordovician, and both Lower and Upper Clinton to be Upper Llandovery. It is not certain that the Lower Llandovery fauna is represented, unless the Upper Medinan, Girandeau, Edgewood, and Brassfield are of this age. The latter is, however, more probably Upper Llandovery. The absence of satisfactory equivalents of the Lower Llandovery is attributed to the incompleteness of the American succession in comparison with Britain.

26. Prof. O. T. Jones.—*The Llandovery Rocks of Llandovery.*

A brief summary of the work of previous observers in the district is given.

In the district around Llandovery three main divisions (A-C) can be distinguished, each capable of subdivision on lithological or faunal grounds as follows :—

		Ft.
C.	Upper Division. Mudstones, shales and grits : *Pentamerus oblongus* occurs commonly.	
C6.	Thin-bedded micaceous shales with bands of micaceous sandstone ; thickness considerable.	
C5.	Soft greenish-blue or dark-blue mudstones	380
C4.	Dark-green fucoidal sandstones with bands of shale and quartzitic sandstone	270
C3.	Pale greenish mudstones passing up into greenish shales .	270
C2.	Like C3	250
C1.	Hard greenish mudstones with calcareous nodules. *Monograptus sedgwicki* common	400
	UNCONFORMITY.	
B.	Middle Division. Greenish mudstones and shales. *P. oblongus* found only at base. *Monograptus decipiens, M. regularis* and *Orthograptus cyperoides* also occur.	
B3.	Hard greenish mudstones	300
B2.	Blue micaceous mudstones, poorly exposed	250
B1.	Hard greenish mudstones, with small calcareous nodules. .	250
A.	Lower Division. Sandy mudstones and blue mudstones passing down into shales and sandstones. *Monograptus incommodus*, &c.	
A4.	Hard tough thick-bedded sandy mudstones with some thin bands of jointed quartzitic sandstones	700
A3.	Blue sandy micaceous barren mudstones with 1 in.-2 in. fossiliferous gritty micaceous bands	400
A2.	Grey shaly mudstones without hard bands passing down into soft dark-blue shales with thin beds of grey sandstone. *Climacograptus tornquisti* at top	900
A1.	Basal group of hard grey quartzitic sandstones and occasional thin conglomerate with interbedded smooth iron-stained dark-blue shales	150

The basement beds (A1) rest upon Upper Bala rocks and the highest group (C6) is overlain, in places, unconformably, by the Wenlock shales ; the total thickness of the formation near Llandovery thus exceeds 4,500 feet. A great unconformity has been mapped at the base of the Middle Division, and another at the base of the Upper. The fossils are mainly brachiopods and trilobites, and the chief forms from each subdivision are enumerated.

27. Mr. G. Andrew.—*The Llandovery Rocks west of Builth, Breconshire.*

A brief summary of the work of previous observers is given. The succession is as follows :—

		Ft.
Wenlock (D).	Blue, thinly bedded calcareous mudstones, with *Cyrtograptus murchisoni, Monograptus priodon, M. crenulatus*, &c. These beds overstep rapidly southwards, and eventually lie directly on the Bala.	

			Ft.
Llandovery (A-C).			Ft.
Upper Group (C)	C4.	"Pale shales." Olive-green, mottled mudstones, with *M. crenulatus* . .	800
	C3.	Pale olive-green sandy mudstones . . .	80
	C2.	Conglomeratic grit and limestone with *Pentamerus oblongus*	25
	C1.	Green mudstones with *P. oblongus* . .	130
		UNCONFORMITY.	
Middle Group.	B.	Pale greenish-grey mudstones with *Monograptus decipiens*	50
		UNCONFORMITY.	
Lower Group.	A4.	Grey sandy mudstones with shelly fossils and *Monograptus atavus*	260
	A3.	Micaceous olive-green mudstones with grit bands. *Stricklandinia lens, Meristina subundata.*	700
	A2.	Dark-grey mudstones with grit-bands near the base	350
	A1.	Massive, well-jointed basal grit, conglomeratic towards the S. . . .	50
		UNCONFORMITY	
Bala.		Blue-black mudstones with *Æglina, Cystids,* &c.	

In the greater part of the district the upper and lower groups are in uncomformable contact. Comparison with the Llandovery area proves that over 1,600 feet of strata are missing. In one locality about 50 feet of the missing strata (B) are exposed.

28. Mr. GEORGE SLATER.—*Glacial Tectonics as Reflected in Drift Deposits.*

Superficial disturbances attributed to glacial action are best developed in association with the softer Mesozoic and Cainozoic formations in Britain. An excellent example of this type of structure was seen during extensive excavations in the area of the Hadleigh Road, Ipswich, between the years 1900-1923.

The disturbed deposits consisted of material derived from five local outcrops of Tertiary formations, each bed having a distinctive lithology. The sequence included Thanet Beds, Reading Sands, Pebble Beds, London Clay with cement stone, and Red Crag. These disturbed deposits rested on an outcrop of Reading Sands of low relief, adjacent to which is a buried glacial channel.

The upper surface of Reading Sands had been moulded into ridges resembling 'roches-moutonnées' with four intervening spoon-shaped basins.

Upon this rippled surface lenticles of London Clay had been stranded and moulded into asymmetrical folds or 'drumloidal curves.' 'Boulders' of Crag had in turn been arranged over these folds, and finally sand and gravel with portions of Crag and strips of London Clay overlain by boulder clay had filled in the basins and converted the central basin into the crest of a hill. The deposits on the exposed sides of the folds were associated with thrust-planes, and those on the leeward sides with 'tip-structure.'

This type of tectonic structure was due to the combined effects of differential movement associated with two pressures varying in intensity and acting at right angles to one another. Pressure from the north was seen to best advantage in the north-east part of the area, whilst that from the west was well displayed in the adjacent railway sections to the south-west.

The outcrops of the disturbed beds are arranged at right angles to the resultant of the pressures on the exposed sides of the folds, but in the direction of the resultant on the leeward sides of the folds.

The disturbed deposits are regarded as having formed bedded englacial material in a body of moving ice, the structure as now seen being the cast of the original structure. The beds have been preserved in the same relative positions as in the glacier, owing to an extremely slow rate of melting of the interstitial ice. This tranquil mode of deposition was due to the blanketing of the whole with boulder clay.

SECTION D.—ZOOLOGY.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 466.)

Thursday, August 7.

1. Mr. F. A. Potts.—*Intracellular Digestion in Invertebrates.*

In the protozoa, when the animal digests its own food, the process is necessarily intracellular. The rest of the invertebrate phyla are divided into two groups. In one of these there is no intracellular digestion by the cells of the endoderm. This includes Annelida, Arthropoda, Echinodermata, and other smaller phyla. In the other group, containing Porifera, Cœlenterata, Platyhelminthes, and Mollusca, some part of the endoderm is often phagocytic. There is usually a preparatory extracellular digestion. In the Cœlenterata this breaks up the food, often consisting of comparatively large animals, into minute particles which are taken up by the cells of the mesenteric filament in which digestion is completed. In the Gastropod Molluscs, however, digestion in the flesh-eating forms is mainly extracellular : in the vegetarians it is largely intracellular. In such an example of the latter class as *Helix* the enzyme in the preparatory extracellular digestion is a cytase, which dissolves the walls of the plant cells and sets their contents free for the intracellular proteolytic digestion which follows. In other cases, besides, intracellular digestion becomes prominent when the diet is specialised, and particularly when it contains elements which are normally indigestible, such as the chloroplasts and nematocysts in the food of the Opisthobranchs and the wood fragments ingested by *Teredo* amongst Lamellibranch Molluscs. Thus intracellular digestion may be a mark of specialisation. In the Arthropods where the capacity for intracellular digestion has been lost, certain forms feed on wood in like manner to *Teredo*, but the function of digestion is apparently performed by symbiotes—e.g. protozoa (Termites) and bacteria (Tipulids).

2. Mr. D. Ward Cutler and Miss L. M. Crump.—*Observations on the Growth and Reproduction Rate of a Ciliate.*

It is well known that when protozoa are inoculated into artificial culture media, the resulting growth is very irregular. Sometimes the organisms fail to increase in numbers, while on other occasions there is a rapid increase during the first day or two, followed by a period of rest. Usually, however, a maximum number is attained in the culture, after which the population decreases gradually, showing, however, considerable variations in the numbers during the process.

The causes of this sequence of events have formed the subject of much research by earlier workers, but, from the results, no definite conclusions have been drawn. A study of the rate of reproduction of a ciliate, *Colpidium colpoda*, has shown that the increase of numbers follows a definite progression, provided that certain factors are controlled. Thus the air supply, the nature of the medium, the number of organisms inoculated, and the food, are important external agents, while the age of the organism used for inoculation is an example of a factor, inherent in the animal, capable of affecting the rate of reproduction.

The action of these modifying factors has been tested on both mass culture and on single ciliates.

The supposed acceleration of reproduction which one organism produces in another (allelocatalysis) has also been tested, but with negative results, though there is evidence that the addition of small quantities of substances similar in nature to 'bios' has a marked effect.

3. Prof. John Tait.—*The Mechanism of Massive Movement of the Operculum of Salanus nubilis.*

4. Prof. W. M. Tattersall and Miss E. M. Sheppard.—*Sex Phases in the Female of Asellus aquaticus (Linn.).*

In the course of an examination of the changes which take place during the breeding season in the female of *Asellus aquaticus*, it was found that adults of this sex occur in one of two forms (1) a non-breeding form, in which the oostegites are present as small rectangular plates, not overlapping those in front or behind, and (2) a breeding form, in which the oostegites are large, foliaceous plates overlapping those in front and behind and those of the other side to form a functional brood pouch. These phases succeed one another rhythmically during the breeding season, a breeding phase being regularly followed by a non-breeding phase and that by a breeding phase again, so that there are two moults between successive broods. This series of events is quite different from that which Mrs. Sexton has found in *Gammarus*. There the oostegites, once fully formed, appear completely developed and functional at each moult, and there is no non-breeding phase between the egg-bearing phases. Once adult conditions are reached each stage of moulting is a breeding egg-bearing stage. Evidence supplied by an examination of a collection of *Phreatoicus* from Australia suggests that the same conditions obtain there as in *Asellus*—i.e. there is an alternation of breeding and non-breeding phases during the breeding season, distinguished by the difference in the size of the oostegites. Further evidence is being sought to determine how far the differences between *Gammarus* and *Asellus* are characteristic of the Amphipoda and Isopoda as a whole. Unconfirmed observations suggest that *Asellus* winters in the non-breeding phase. The relation of this phenomenon in *Asellus* to the phenomenon of high and low dimorphism known among the males of other Crustacea is discussed.

5. Mr. J. S. Huxley.—*Linkage in Gammarus chevreuxi.*

1. *Sexual difference in linkage intensity.*—The crossover value between the factors B and C in the Amphipod *Gammarus chevreuxi* is markedly different in the two sexes. In the female it is close to 50 per cent., while in the male it is about 20 per cent. Such a sexual difference in C.O.V. has only been found elsewhere in Orthoptera (*Paratettix* Nabours).

This is of some theoretical interest, as it indicates that in Crustacea the male sex is probably heterogametic, for in all animals so far investigated the heterogametic sex shows stronger linkage-intensity than the monogametic—e.g. in Drosophila there is no crossing-over in the male, in the silkworm none in the female. In rats and mice there is crossing-over in both sexes, but slightly less in the male. The data from monœcious plants do not bear upon the problem.

2. Data are presented as to variations of linkage-intensity and their inheritance.

3. The possibility of the mechanism of linkage in Gammarus and some other forms being different from that in Drosophila is discussed.

6. Dr. F. A. E. Crew.—*Studies in the Sexual Differentiation of the Fowl.*

An account of certain experimental work which suggests that:—

The type of differentiation of the embryonic gonad of the fowl is determined by the type of internal environment in which it finds itself, the type of internal environment being determined by the genetic constitution of the individual. In an internal environment of 'femaleness' the embryonic gonad becomes an ovary, in one of 'maleness' a testis. The bird has an ovary because she is a female, a testis because he is a male.

The type of plumage is determined by the type of metabolism which obtains at the time of its development, and is not a response to any specific influence of an internal secretion elaborated by the differentiated gonad.

Size, shape, and carriage are characters that are not influenced by the type of gonad, as is clearly shown in the case of the developmental capon and poularde.

7. *Reports of Committees.*

8. Dr. J. W. Heslop Harrison.—*On Hybrids between British and Canadian Lepidoptera.*

The hybrid unions brought about fall into five groups :—

(I.)—(*a*) *Oporabia omissa* (mihi) ♀ × *O. autumnata* ♂.
(*b*) *Oporabia omissa* ♀ × F_1 (*O. filigrammaria* ♀ × *O. autumnata* ♂) ♂.
(*c*) F_1 (*O. filigrammaria* ♀ × *O. autumnata* ♂) ♀ × *O. omissa* ♂.
(*d*) F_2 (*O. filigrammaria* ♀ × *O. autumnata* ♂) ♀ × *O. omissa* ♂.
(*e*) *O. filigrammaria* ♀ × *O. omissa* ♂.

The outstanding feature here was the discovery that the species named here *Oporabia omissa*, and generally called *O. dilutata* in America, was quite a distinct form more closely allied to *O. autumnata*. It differs from that form in the obscurely hooked valves of its male genitalia, its size, wing pattern and larva. All the crosses listed, with others of more complex origin, were reared and both sexes obtained, but attempts to secure an F_2 generation failed, owing to the sterility of the F_1 hybrids. Segregation of *autumnata* and *filigrammaria* characters was noted in crosses (*b*), (*c*) and (*d*). In all the broods structural abnormalities in the way of interpolated segments were noted in the larvae.

(II.)—(*a*) *Poecilopsis rachelae* ♀ × *Lycia hirtaria* ♂.
(*b*) *Nyssia zonaria* ♀ × *P. rachelae* ♂.
(*c*) *P. rachelae* ♀ × *N. zonaria* ♂.

Here, again, only F_1 broods were possible. An important fact was the appearance of intersexes in cross (*c*). Structural defects similar to those mentioned above were of free occurrence.

(III.)—*Ennomos quercinaria* ♀ × *E. subsignaria* ♂ with back crosses.

The F_1 ♀, proving fertile, was back-crossed on both parent species when segregation in wing colour was observed in the offspring. At the same time the reciprocal pairing, repeatedly produced, yielded eggs which failed to hatch.

(IV.)—(*a*) *Orgyia antiqua* ♀ × *O. badia* ♂ (Brit. Columbia and Oregon).
(*b*) *O. badia* ♀ × *O. antiqua* ♂.
(*c*) *O. antiqua* ♀ × *O. nova* ♂ (Montreal, Nova Scotia, Maine).
(*d*) *O. nova* ♀ × *O. antiqua* ♂.

This set of pairings was secured with extreme facility, yet the resulting ova only hatched when the ♀ parent was of European origin, the test matings exceeding 100 in the critical cases. F_2 broods were reared from (*a*) and (*c*). In the cross (*a*) the melanism introduced by the *badia* ♂ proved dominant, and a normal 3 : 1 ratio appeared in the F_2 batches. On the other hand, in the cross between the Eastern insect and the European form, a persistent blend with but little indication of segregation in F_2 and back crosses was the result.

(V.)—(*a*) *Orgyia leucostigma* ♀ × *O. antiqua* ♂.
(*b*) *O. antiqua* ♀ × *O. leucostigma* ♂ (Toronto, Montreal).
(*c*) *O. vetusta* ♀ × *O. antiqua* ♂.
(*d*) *O. antiqua* ♂ × *O. vetusta* ♀ (California).

In all these cases eggs were duly laid, but none hatched.

9. Mr. A. D. Peacock.—*Sexuality in the Saw-fly* (*Pristiphora pallipes*, Lep.): *a Study in the Evolution of Parthenogenesis.*

In England, and apparently in Canada, *P. pallipes* is almost completely asexually female-producing, as out of 600 individuals bred during three years only four were males—one from stock, two from eggs treated by immersion in magnesium sulphate (sol. 2 per cent.), the fourth from eggs treated by immersion in warm water (30° C.); the effects of these experimental conditions upon male production and sexuality are undetermined; male sexual instincts are not so patent as in other species; the females ignore the males (a-dechandry), but a single apparently genuine pairing was at last obtained; the paired female laid twenty-two eggs, nineteen pupæ were reared, and seventeen females derived to date (May 30). Possible explanations of this thelyotoky are (1) ineffective pairing; (2) unfertilised eggs; (3) the chromosome complex of the possibly fertilised eggs permits the production of females only, of nature similar to Bridges'

Drosophila super-females; each explanation implies that *pallipes* has not only adopted thelyotokous parthenogenetic reproduction, but that its chromosome complex has become a fixed diploid, one which, moreover, is almost incapable of reduction to the haploid condition and, still more unlikely, to a heterogametic condition; consequently, in rare and probably unnatural pairing the female dispenses with fertilisation, or its 'femaleness' suffices to destroy the 'maleness' introduced by the spermatozoa, whether the spermatozoa are haploid—*c.f.* drone bee—or of two potentialities—*c.f.* other insects.

10. Dr. F. A. Dixey, F.R.S.—*On Scent-distributing Structures in the Lepidoptera.*

In the *Pierinæ*, or 'white butterflies,' the scent-distributing scale is usually a rather highly specialised structure, which in many members of the group takes the form of a flattened lamina provided distally with a fringe of chitinous filaments, and proximally with a fine flexible footstalk. This latter expands into an accessory disc, which varies from species to species in size and character. The disc is inserted into a specialised socket, within or beneath which are found the cells which secrete the scented material.

Though no doubt exists as to the respective functions of cell and scale, diverse views have been held as to the exact mode in which the scent escapes. Weismann thought that the secretion passed from the mother-cell by way of disc and footstalk into channels within the substance of the lamina; that these channels were prolonged into the fimbriæ, or distal filaments, and so, through terminal orifices of the latter, into the open air. Illig, on the other hand, contends that there is no proof that the fimbriæ are pervious, and attributes the escape of the odour to pores on the surface of the lamina. The minuteness of the structures involved makes investigation difficult, and the interpretation of the microscopic appearances is attended with much uncertainty. The present writer, however, finds that the disc is in connection with the subjacent cell, and that a space may exist within the lamina. He has failed to find satisfactory evidence of the existence of pores.

11. Prof. A. E. Cameron.—*Some Tabanidæ of Saskatchewan, their Parasites and hitherto undescribed pre-imaginal and imaginal Stages.*

The material on which the substance of the paper is based was collected in northern Saskatchewan with the idea of obtaining information on the early stages of the Tabanid family. Only a comparatively few species are discussed—namely, *Chrysops mœrens, C. mitis, C. fulvaster*; *Hæmatopota americana*; *Tabanus septentrionalis, T. reinwardtii*, and *T. insuetus*—and in each case descriptions of the pre-imaginal stages which have not previously been published are furnished. It is felt that whilst the paper is not exhaustive, any additions to our knowledge of this important family will be acceptable as a contribution to the present rather meagre information concerning the life-histories of our North American species. The author hopes to enlarge the scope of the work in future papers, a hope which is strengthened by the abundance of the Tabanidæ in Western Canada. In many species the males are unknown, and the author has been enabled by careful rearing of the young stages to obtain excellent series of the males of the species above enumerated, from which descriptions have been made. Parasitism of the Tabanidæ and their general habits are briefly discussed, as well as the importance of the eye-markings in the identification of species.

Friday, August 8.

12. Joint Discussion with Section M on *Soil Population.*

Afternoon Excursion to the Forks of Credit River.

Monday, August 11.

13. Presidential Address by Prof. J. W. Gamble, F.R.S., on *Construction and Control in Animal Life.* (Page 109.)

14. Mr. J. T. Cunningham.—*Lamarckism and Secondary Sexual Characters.*

It has long been known that in vertebrates, especially in mammals, the secondary characters of the male do not develop normally after castration. It has been proved that the connecting link between the development of these characters and the gonads consists of the internal secretions or hormones of the latter organs, circulating in the blood and lymph.

The structural sexual characters, as distinct from colour, are the result of local hypertrophy of the kind which would be produced by the irritations and stimulations caused in the sexual behaviour of the animals, such as fighting, courtship, or holding the female. The neo-Lamarckian theory proposed by me to explain the evolution of these characters is that the hypertrophy or excessive growth repeated in each generation ultimately became hereditary, but was only developed by heredity in the presence of the hormones from the gonad which was present when it was originally produced. This theory thus affords an explanation of the influence of the hormones of the gonads on the development of somatic sexual characters, whereas no other theory throws any light on this influence, since the characters in question are not in themselves essentially sexual or reproductive, and may occur in almost any part of the body, or may be entirely absent.

The influence of the hormones from the gonads in birds has been found to be different from their influence in mammals. The male plumage in ducks, fowls, and pheasants is not suppressed by castration of the male bird, but on the other hand removal of the ovary in the hen is followed by development of the male plumage. The absence of male plumage in the normal hen is therefore due to its suppression by the ovarian hormone. The explanation of this is discussed in the paper. Even more remarkable is the fact that in hen-feathered breeds of poultry castration of the male results in the development of the male plumage which is normally absent.

The absence of any effect on somatic sexual characters after castration in moths and the subject of parasitic castration in Crustacea are briefly considered in the paper.

15. Prof. D. M. S. Watson, F.R.S.—*Palæontology and Mendelism.*

16. Dr. E. H. Craigie.—*Changes in Vascularity in the Brain between Birth and Maturity.*

Quantitative measurements of the vascularity of fourteen selected regions in the brain stem and the cerebellum of the albino rat at different ages reveal the facts that the brain is much less richly supplied with blood vessels at birth than in later life, and that there is relatively little difference in the capillary supply of the different centres at this age.

The vascularity changes little during the first five days, but increases somewhat in most regions by the tenth day. Between the tenth and the twenty-first days there is a rapid proliferation of capillaries, so that the vascularity in all but one of the centres studied in the brain stem reaches a maximum apparently about the latter age. The sensory centres, moreover, become in general richer than the motor ones, the relations being similar on the whole to those in the adult.

The cerebellar centres, however, do not reach their maximum vascularity until the one-hundred-and-forty-days-old stage, at which time the capillary supply of the chief vestibular nucleus is also at its richest.

After the maximum vascularity has been reached, there is a gradual decrease in capillary richness.

It is evident that the richness of the vascular supply is related more to the requirements for functional activity than to those for growth.

17. Prof. J. W. Mavor.—*The Effect of X-rays upon the Transmission of Mendelian Characters.*

Afternoon Excursion on Lake Ontario.

Tuesday, August 12.

18. (A) **Joint Discussion** with Section K (*q.v.*) on *Species and Chromosomes.* (Page 452.)

(B) Subsectional Meeting as follows (Nos. 19-25):—

19. Prof. E. E. PRINCE.—*Biological Board and Marine Research Stations of Canada.*

Owing to the close relation of the British Association with the founding of the Biological Board of Canada, under which the several research stations have been carried on in the Dominion, a special interest attaches to their origin and work.

Following suggestions brought before the British Association at the Toronto meeting in 1897, a committee was appointed by the Association, and through its efforts the sum of $15,000 was voted by Parliament to equip a station and maintain it for five years, and a board was appointed with representatives among its members from five universities.

For some years a floating station was used, but in 1908 a permanent building was erected near St. Andrew's, N.B., and in 1909 a similar Pacific station was built near Nanaimo, B.C., and a third one was also carried on for some years later on Georgian Bay, Ontario.

These stations are purely for research purposes, and only qualified workers are admitted. Fisheries problems have always been most prominent in each season's programme, but many other important researches have been carried on, among which the investigations on insulin are especially notable. Striking results have also been accomplished in an extensive survey of currents and tidal movements in Canadian Atlantic waters by means of drift bottles, a piece of work which has taken on an international character, and which is of great importance in connection with the migrations of food fishes.

20. Prof. A. G. HUNTSMAN.—*The Circulation of the Water off the Canadian Atlantic Coast.*

The distribution of planktonic forms, including the larvæ of fishes, has been found to indicate a certain type of circulation. The same type is indicated by a study of temperatures, salinities, and densities. Extensive series of experiments with drift bottles carrying drags have demonstrated the definiteness of this circulation, its rate, and certain minor variations. The course of the water movement is determined by the rotation of the earth, and is such as to keep land or banks on the right hand; that is, clockwise around banks and islands, and contra-clockwise around basins. The chief motive power would seem to be the tidal oscillations, converted into a circulatory movement by the effect of the earth's rotation.

21. Prof. A. G. HUNTSMAN.—*Certain Limiting Factors in the Distribution of Marine Animals.*

An attempt has been made to correlate the distribution of a number of marine animals with the extent of certain definite physical conditions. Experiments have been performed to test the endurance of these animals to natural extremes in the physical conditions. Temperature, salinity, and light have been found to be effective in limiting distribution, and thus determining the type of fauna.

22. Prof. W. A. CLEMENS.—*Limnobiological Investigations in Ontario in Relation to Fishery Problems.*

The commercial and game fishes occupy a very important place among the natural resources of the Province of Ontario. In view of this fact the Department of Biology of the University of Toronto has instituted a definite plan for the investigation of various problems connected with tho fisheries. Its chief

energies along these lines have been devoted to a study of Lake Nipigon, the first in the Great Lakes Chain. The lake is 1,752 square miles in area, with a maximum depth of 402 feet, and has been open to commercial fishing for the past eight years only.

The central aim in the investigation has been to obtain data in regard to the natural annual production and its utilisation. To this end three main lines have been followed : (1) A study of the physical features such as the distribution of temperatures, oxygen, carbon dioxide, &c., and the relation of these factors to the fauna and flora; (2) the food supply for fish, involving qualitative and quantitative distributional studies of the plankton and the fauna of the bottom; (3) the fish themselves in regard to taxonomy, life histories, relative abundance, distribution, food, rates of growth, &c.

The investigation has yielded much information in respect to the general ecological conditions existing in the lake and to economic questions such as competition for food among fish, rates of growth, correlations of age with length, weight, and girth, size of fish taken in nets of various sized meshes, and rate of mortality. In this connection special consideration has been given to such commercial fish as the common whitefish, the lake sturgeon, and the lake trout.

23. Mr. W. J. K. Harkness.—*Determination of the Rate of Growth and Age of Sexual Maturity in the Sturgeon (Acipenser rubicundus).*

The rate of growth of the sturgeon was determined by a study of the otoliths, and upon this basis the age of an individual can be estimated. From such data the following studies were made : The variation in the rate of growth of the fish at different ages, the changes that take place in external form at different periods of its life, and the age at which it becomes sexually mature. This last point is of particular significance to the sturgeon fisheries and in connection with artificial propagation.

24. Prof. W. J. Dakin and Mrs. C. M. G. Dakin.—*The Physiology of Nutrition in Aquatic Animals.*

The authors have continued their experiments with Axolotls, Goldfish, Plaice eggs, and Anodon. The oxygen consumption during various periods and under varying conditions of nutrition has been determined, and the rates of metabolism have been calculated therefrom. The results completely contradict those obtained by Pütter, which he set forth with his theory that the main source of nutrition of aquatic animals lies in dissolved organic compounds. The experiments bring out interesting relationships between the oxygen consumption, rate of metabolism, and the partial presence of oxygen, temperature, starvation, &c.

25. Mrs. Kathleen F. Pinhey.—*Acartia clausi var. hudsonica nov. var. A contribution towards the Correlation of the Pelagic Copepod Coastal Fauna of Northern Europe and North America.*

The two marine copepods *Acartia clausi* Giesbrecht and *A. longiremis* (Lilljeborg) have been found to be equally common off the southern and western coasts of Norway, where they are often taken together. *A. longiremis*, whose extra-Baltic range extends from the British Isles to the Polar Basin, is more neritic (inshore) in its occurrence, while *A. clausi*, which only exceptionally strays into the Arctic Circle, is more pelagic (offshore). Considering what we already know of the copepods of the Canadian plankton, it is not surprising to find that *A. longiremis* is constant in its more obvious characters on both sides of the North Atlantic, while *A. clausi* is not so identical with its old-world representative, inasmuch as there is an absence of certain distinctive denticles on the edge of the last segment of the forebody.

There is some evidence that *A. longiremis* may present local fluctuations in certain characters, but these do not seem sufficient to justify the introduction of varietal names for this species at present.

The representative form of *A. clausi*, which we have here, is a dominant index type in Hudson Bay and on the North Atlantic and North Pacific coasts, and for this form the varietal name of *hudsonica* is proposed. This discrimination is of interest, not because of the trivial characters involved, but in connection with the correlation of ecological conditions on both sides of the North Atlantic Ocean, as well as upon the opposite coasts of the North American Continent.

26. Miss K. E. Carpenter.—*On the Biological Factors involved in the destruction of River-Fisheries by Pollution consequent on Lead-mining.*

An account of a preliminary investigation of this subject in the Aberystwyth District of Cardiganshire was submitted to Section D at the Hull meeting of 1922, when attention was drawn to the fact that circumstantial evidence, collected in the course of a field-survey, seemed to tell *against* the popular theory of direct extermination of fishes by the clogging of their gills by adherent galena-particles, *in favour* of an alternative hypothesis, newly suggested by the author—that of the efficacy of extremely dilute solutions of lead-salts, such as occur in the polluted waters of the local rivers Rheidol and Ystwyth.

Since that date full-time investigations have been carried on with the aid of a grant from the Department of Scientific and Industrial Research; experiments in field and laboratory have established the following facts :—

(*a*) Fishes can live, and apparently suffer no injury, in direct contact with lead-containing river-grit and lead-containing sediment taken directly from a mine dump.

(*b*) Fishes can live in the polluted River Rheidol itself for long periods during calm weather.

(*c*) They die soon after the onset of a flood-period, without symptoms of inflammation or bruising of the gills or other external parts.

(*d*) The Rheidol water at such a season contains measurable quantities of lead in solution—no such substances can be detected in it during the calms.

(*e*) The 'flood-water,' when *filtered* and used in the laboratory, is fatal to fishes and to invertebrate species selected as typical of the local freshwater fauna. This quality is *not* due to the degree of hydrogen ion concentration, but to its dissolved content.

(*f*) The neighbouring rivers, Teifi and Meurig, though affected until recently with lead-mining near their banks, are rich in fish life—trout, minnows, sticklebacks, and salmon occur in these waters.

(*g*) The sediments from these two rivers contain lead-grit, but their waters, even in flood-time, contain no appreciable amount of lead in solution.

The effective agent in the destruction of local river fisheries is clearly indicated, and the old precaution of 'sedimentation,' which aimed at keeping lead-grit out of the rivers, is seen to be futile; a new method of treatment may be suggested in outline, for elaboration by the technical expert.

27. Mr. E. Melville Du Porte.—*Some Endophytic Protozoa. A contribution to our knowledge of the Protozoa living in the latex of plants.*

A survey made in 1923 revealed the presence of amœbæ and flagellates in the latex of ten species of common plants and several exotic plants. The organisms have been shown to hibernate as minute resting cells in the overwintering stems and roots of their hosts. They have been shown to pass into the seeds of *Asclepias syriaca* and infect the seedlings. Results of morphological, cultural, and transmission studies will be given.

28. Prof. E. M. Walker and Miss Norma Ford.—*Some Features in the Anatomy of Grylloblatta, a primitive Orthopteroid Insect.*

Grylloblatta, a remarkably synthetic genus of Orthopteroid insects discovered by the senior author in 1913, combines characters of most of the lower pterygote

orders with certain features suggestive of the Thysanura. Recently a few live specimens have been obtained and preliminary studies of the internal organs made.

Resembling a stone-fly larva in general appearance and in the structure of the head capsule, thoracic nota and slender jointed cerci, it approaches the cockroaches and termites in the mouth-parts, legs, cerci and genitalia, but has a prominent exserted ovipositor like that of a long-horned grasshopper, and possesses also certain characters suggestive of Mantids, Phasmids, Embiids and Dermaptera (earwigs). Orthopteroid also is the presence of styli throughout life in the male and in the immature stages of the female, but the division of the sternum of the 9th abdominal segment of the male, which bears the styli, into median sternite and lateral styligerous coxites, is a primitive feature suggestive of certain Thysanura. Another Thysanuroid character is the apparent independence of the tracheal systems arising from each abdominal spiracle, and the absence of muscles connected with the latter is also noteworthy. The general features of the internal anatomy, which have been only partly worked out, confirm our conclusions as to the systematic position of Grylloblatta as based on the study of its external structure.

29. Sir William Herdman, F.R.S.—*Note on the Structure and Affinities of Ramulina.* (Presented by Prof. W. J. Dakin.[1])

This large calcareous organism, forming masses up to 8 cm. in diameter and covering considerable areas of the sea-bottom, was dredged by Herdman in 1902 from depths of about 100 fathoms in the Indian Ocean south of Ceylon, and was then identified as a massive Foraminifer related to the genus *Ramulina.* It was described in detail and figured by Dakin in 1906 as a new species under the name *Ramulina herdmani.* Since then the Ceylon material has been examined by several other zoologists and regarded by some as a sponge, by others as a Foraminifer, or an aberrant Protozoon related to Foraminifera, or a compound of two or more organisms.

It is composed of long, slender, calcareous tubes or pipes and rounded massive ampullæ united in various ways to form a complex mass, and it is crowded with siliceous sponge spicules, both loose in the interior of the protoplasm and also built into the calcareous walls and sometimes projecting in tufts from the growing ends. But these spicules represent and are evidently derived from several different groups of sponges, such as Monaxonida, Tetractinellida, and Hexactinellida. The walls of the pipes are penetrated by regularly arranged, closely placed tubules opening on the surface, and these as well as the main tubes are lined by a chitinous (?) membrane. There are various other complications which give rise to appearances very unusual in the Foraminifera, but which approach the structure seen in *Carpenteria* and *Polytrema* as figured by Mœbius and by Hickson. I have no doubt that the Ceylon 'Ramulina' (which may require to be placed in another genus) is a Foraminifer which will take its place in a series of massive forms of advancing complexity, such as *Carpenteria, 'Ramulina,' Sporadotrema, Polytrema, Homotrema.*

(Specimens were exhibited.)

Wednesday, August 13.

30. Discussion on *The Origin of Land Vertebrates.* Opened by Prof. E. S. Goodrich; Prof. D. M. S. Watson, Mr. J. T. Cunningham, Prof. W. K. Gregory following.

31. Dr. Nellie B. Eales.—*The Anatomy of a Fœtal Elephant.*

A fœtal African elephant was obtained by purchase from the Belgian Congo. Of the eleven other fœtuses known, eight were not investigated anatomically, one was fit for skeletal examination only, and two belonging to the British Museum have not yet been described. The present specimen is fairly well preserved, and will be used for the dissection of the muscles, nerves, and skeleton of the head.

[1] Sir William Herdman died shortly before the Meeting.

The rarity of unmacerated fœtuses of this large mammal is the justification for bringing the notice of it before this meeting of the Section, in the hope that anatomists will suggest problems that might be solved during the course of its dissection.

The fœtus is probably less than half term, for it is certainly younger than Toldt's eleven-month Indian specimen. The determination of the age is based on development and not on measurements, which, owing to the curvature of the body and the difference in the species, are misleading. The characters of the Proboscidea, and of the African species in particular, are well marked, and external features throw little light on the evolution of either.

The external anatomy, the histology of the skin and of the temporal gland, and certain fœtal peculiarities such as the cushion and pit on the upper lip, are described and discussed.

32. Prof. W. K. Gregory and Mr. M. Kellman.—*The Dentition of Dryopithecus and the Origin of Man.*

Parts of three lower jaws of fossil anthropoids of the genus *Dryopithecus* have recently been discovered in the Siwaliks by Barnum Brown, of the American Museum of Natural History, New York. The fossils include a nearly complete fore-part of the jaw, and two left halves, with the cheek teeth beautifully preserved in both. They were found in three successive horizons of the Lower and Middle Siwaliks, and the series as a whole reveals a progressive modification of the premolars in the direction of the later anthropoids. The new specimens thus afford a welcome addition to knowledge of the Siwaliks anthropoids described some years ago by Pilgrim of the Indian Survey. The "*Dryopithecus* crown pattern" of the lower molars is fully expressed in all the Siwaliks anthropoids, and has been traced, with detailed modifications, not only into the molar crown patterns of each of the existing anthropoids, but also into those of primitive human types. The anterior premolar of *Dryopithecus* is laterally compressed, but the homologous tooth in chimpanzees varies from a compressed form, recalling that of *Dryopithecus*, to an almost human, bicuspid stage.

These facts, in the light of cumulative anatomical evidence for the relatively close relationship of man with the existing anthropoids, not only afford strong support for Darwin's view that man is an offshoot from the anthropoid stem, but tend to indicate that the distinctively human modifications of the dentition took place after the Middle Miocene.

SECTION E.—GEOGRAPHY.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 466.)

Thursday, August 7.

1. Dr. Marion I. Newbigin.—*The Training of the Geographer.*

Existing facilities for the training of professional geographers in the universities and colleges of Great Britain, more especially from the standpoint of the needs of the future teacher. Opportunities for obtaining special qualifications in the subject are of very recent origin, and thus many of the limited number of appointments, whether professorships, readerships, or lectureships, in the higher institutions of learning are held by men who have approached geography by way of some other subject, and not directly. The bearings of this fact are discussed in some detail. A critical analysis is then made of the chief qualifications open to the student, whether pass degrees, diplomas or honours degrees, and the ideal curriculum for the future teacher discussed.

2. Mr. J. Bartholomew, M.C.—*Modern Developments in the Use and Construction of Maps.*

Recent factors affecting the use made of maps, political and scientific.—Flying maps.—Use of wireless.—Aerial and other new methods of surveying.—The vital

importance of maps in education.—Maps applied to illustrate special purposes, e.g. population maps, &c.—New projections and recent ideas concerning the use of certain old ones.—Suggestions for assisting children to construct their own maps and thus increase their interest in geography.

3. Mr. J. H. Reynolds.—*The Work of the Permanent Committee on Geographical Names for British Official Use.*

Need for standardisation of place names.—R.G.S. rules for orthography, 1885.—The Geographic Boards of the United States, 1890, and Canada, 1898.—Effect of Great War and Peace Treaties.—Origin and constitution of P.C.G.N., 1919.—Revision of R.G.S. rules : the R.G.S. II. system.—Conventional names.—National spellings where Latin alphabet is used.—Diacritical marks.—Translation of non-Latin alphabets, Cyrillic, Greek, Arabic, &c.—P.C.G.N.'s adoption of ready-made official lists.—Indian, Chinese, and Japanese names.—Unwritten languages.—Native names according to R.G.S. II. system. Arbitrary systems invented by missionaries, &c., not adopted; Fijian, Sechwana.—Method of preparing lists of names.—Revision by competent authorities.—All lists of names in British Empire submitted to local governments before final publication.—Dominions representatives.—Irish names.—Other work of P.C.G.N.—Inquiries about orthography and pronunciation welcomed.—Interest in P.C.G.N.'s work displayed in United States and Canada.

4. Presidential Address by Prof. J. W. Gregory, F.R.S., on *Inter-racial Problems and White Colonisation in the Tropics.* (Page 125.)

5. Mr. E. M. Dennis.—*The Work of the Topographical Survey of Canada.*

This Branch of the Department of the Interior has been making surveys since 1869. Before the war a very large area of new land in Western Canada was subdivided into farms, but, as opportunities offered, other work was undertaken, such as photo-topographic, exploratory, and inter-provincial boundary surveys. During and since the war the activities of the Branch have been largely devoted to filling in the details of the earlier surveys. Lands are being classified for their suitability for agriculture. A systematic topographic survey has been commenced, the resulting maps being on scales of three miles and one mile to the inch. Experimental work with aerial photography as an aid in surveying and mapping is receiving considerable attention.

6. Mr. W. H. Boyd (Chief Topographical Engineer, Geological Survey).—*The Geological Survey's Part in the Topographical Survey of Canada.*

The work, in the field and office, of the topographical division of the Geological Survey.—A sketch of the creation of the division, and the method of selecting and training topographers.—Various methods used in different parts of Canada.—The standard sheet system, scales and types of maps produced.

7. Mr. A. M. Narraway (Controller of Surveys).—*Practical Application of Aerial Photographs to Surveys in Canada.*

During the past two seasons considerable experimental work has been carried on in Canada in the utilisation of aerial photography for mapping purposes. The results obtained have enabled the Topographical Survey of Canada to apply these views in a practical and economical manner to supplement ground surveys. Marked progress has been made in mapping by oblique aerial photographs the important mineralised areas in Northern Manitoba and the intricate system of waterways in that district, and in obtaining information relative to forest cover by this means. Aerial photographs are also being used extensively in land classification, revision, and soil surveys.

8. Mr. W. H. Herbert.—*The Magnetic Survey of the Topographical Survey of Canada.*

Description of the magnetic survey of the Topographical Survey of Canada from 1880, the date of its inception, to the present; explaining how a most

extensive magnetic survey has been carried out in new and difficult territory at absolutely no expense by combining it with the land survey.—The instruments used, the reasons for their adoption, their accuracy in the field, and the method of standardisation and observing.—The method used in correcting observations for diurnal inequality and in reducing to epoch in compiling isomagnetic maps.—A general summary of this work accomplished to date : observations, secular change and diurnal inequality observations, and maps and publications.

9. Mr. N. Ogilvie.—*The Work of the Geodetic Survey of Canada.*

The most important functions of the Geodetic Survey are to establish, in a permanent manner, a series of points of reference, at convenient distances apart, whose geographical position have been accurately determined by nets of triangulation and astronomical observations. It also determines the accurate elevations above sea-level of permanently marked points along main railways and in the principal towns and cities, by lines of precise levelling. It therefore forms the basis and provides the foundation which, without it, would have to be duplicated in some manner by each separate organisation carrying on surveys, Federal Departments, Provincial Governments, Municipalities, &c. This centralisation prevents duplication and expense, and assures efficiency and economy. Federal and Provincial Departments and Municipalities realise these points, and, wherever possible, are turning over this feature of their operations to the Geodetic Survey, which can perform it most satisfactorily and economically. When connected together by the Geodetic Survey data, older surveys can be made of good use and the expense of map-making is very materially reduced, the decrease in expense being larger as time goes on. With new surveys errors can be discovered and localised, and the surveys can be accurately connected to other Canadian surveys, past and future.

10. Dr. W. Bell Dawson (Superintendent of Tidal Surveys of Canada).—*The Survey of Tides and Currents in Canadian Waters: Progress and Methods*, 1893 *to* 1924.

A concise outline is given of the general procedure in carrying on a survey of tides and currents in waters where there was little or no information to begin upon. On the two coasts of Canada the tides are extremely varied, and exemplify almost every tidal feature. Some indication is given regarding methods and appliances employed, in the hope of being helpful to parts of the British Empire where less progress has been made. The work of the Survey includes : (1) Investigations of currents and tidal streams, and information on the temperature and salinity of the waters; (2) tidal observations as a basis for tide-tables, including methods of analysis and calculation; (3) tide-levels, and determination of mean sea-level.

Friday, August 8.

11. Dr. Vaughan Cornish.—*Wind, Wave, and Swell on the North Atlantic Ocean.*

During a voyage from Southampton to Trinidad and back by R.M.S. *Oruba* the author took the period of the waves several times daily, from which their speed was calculated. The speed of the wind was ascertained by means of a Robinson anemometer lent by the Meteorological Office.

The speed of the wind ranged from 13.9 to 23.6 statute miles per hour. That of the waves was in all cases less, the difference ranging from 1.0 mile an hour to a little more than 8.0 miles an hour. When swell and wave ran precisely in the same direction, and on one day when no swell was recorded, the speed of the wave was so nearly equal to that of the wind that the breeze blowing over the ridges was only equal to the 'light air' which barely suffices to give steerage way to a fishing smack, and would be detected on land by drift of smoke but would not move a wind-vane.

When the swell followed but crossed the wave the difference in speed of wind and wave was greater, and the difference increased rapidly when the crossing swelling swell was meeting, instead of following, the wave. When the waves

were much slower than the wind their height was always small, and sometimes their fronts were short and irregular. It was evident that the growth of waves in both length and height was much hindered by a crossing swell, and it can be safely inferred that the general absence of swell upon enclosed seas favours the rapid rise of waves.

12. Mr. D. W. McLachlan (Engineer-in-Charge, St. Lawrence Ship Canal).—*The Proposed Improvements of the St. Lawrence and Great Lakes System for Power and Navigation.*

The present canals and river improvements between the Great Lakes and the ocean.—Improvement under way across the Welland peninsula and those proposed in the St. Lawrence between Lake Ontario and Montreal.—Power developments proposed.—Types of ships.—Economics of the problems.

13. Dr. R. M. Anderson.—*Scientific Work of the Southern Party of the Canadian Arctic Expedition*, 1913-18.

The work of this party was confined to the mainland and adjacent islands of the Western Arctic, the relative importance of the investigation being (1) geological, (2) geographical, (3) anthropological, (4) biological, (5) photographical. The primary work accomplished was the investigation and areal mapping of copper-bearing and associated rocks of the mainland between Cape Parry and Kent peninsula. Unfavourable ice conditions caused delay for one year in region farther west, and resulted in mapping of the whole northern coast of Yukon Territory and Firth River, as well as the main channels of the Mackenzie River delta. Many detailed maps were made; anthropological studies of Copper and other groups of Eskimo; large biological collections.

14. Prof. W. H. Hobbs.—*The Glacial Anticyclone.*

15. Dr. R. M. Anderson.—*The Present Status and Future Prospects of the Larger Mammals of Canada.*

Some Canadian mammals already on the verge of extinction.—Many species will be saved by fur-farming.—The state of the pronghorn antelope the most precarious, only a few thousand remaining in the whole of North America.—Bison and elk will persist in semi-domestication; the white-tailed deer will increase in bush-clearings in non-agricultural districts, and the moose will survive to a lesser extent.—Arctic and sub-arctic lands beyond range of cultivation support many wild caribou and a few musk oxen.—Possibilities of reindeer industry and domestication of musk-ox.—Need of investigation of extent of Arctic pastoral areas.—Tundra is not prairie.—Extensive sterile areas.—The problem of transport in the industry.

16. Joint Discussion with Section H on Prof. J. W. Gregory's Address. Speakers: Mr. H. J. Peake, Dr. F. C. Shrubsall, Dr. A. Hrdlicka, Mr. E. N. Fallaize, Dr. Vaughan Cornish.

Monday, August 11.

17. Joint Discussion with Section C (*q.v.*) on *Changes in Sea-level.* (Page 384.)

18. Dr. C. Christy.—*Cape to Cairo Progress.*

Present position of Cape to Cairo rail and river transport routes.—First laid section of railway from Cape Town and gradual advance northward.—From diamond fields to Rand, Victoria Falls, across Congo to Khatanga.—Equatorial rail and river section to Stanley Falls, Lake Albert, and Rejaf on the Nile.—Alternative route via Victoria Nyanza and Uganda to Nile.—Congo forest

and pygmies.—Mountains of the Moon.—Navigability of the Nile.—Rejaf to Khartum and Sudan Sudd region.—El Obeid and Sudan Railway.—The Nile-Congo divide and the latest mineral milestone.—Khartum to Cairo.

19. Prof. P. M. Roxby.—*Distribution of Population in China.*

Distribution of population in relation to (*a*) physical geography and natural regions of China, (*b*) its economic and political significance.—Census returns.—Attempts to map distribution by *hsiens*.—Results only approximate, but give for first time essential geographical distribution.—Main and secondary regions of concentrated population.—Review of distribution in relation to natural divisions.—Large cities.—Over-population.—China as a whole can support more people.—Overflow of population.—An estimate of probable movements in the near future.—Present grouping of population presents obstacles to political consolidation.—The outlook and regional relations of main nuclei of population.—The rôle of the Lower Yang-tse and especially the Hupeh basin in political consolidation of the Chinese people.

Tuesday, August 12.

20. Miss E. C. Semple.—*The Influence of Geographic Conditions on the Ancient Mediterranean Religions.*

21. Mr. T. Adams (Past-President of the Town-Planning Institutes of England and Canada) and Mr. H. L. Seymour. — *Some Problems of Urban Growth in America.*

Concentration of population in large cities of the American continent similar to that which exists in European cities.—Includes industrial, business and housing as well as traffic congestion.—As modern cities grow larger the economic advantages of centralisation seem to diminish and a certain amount of decentralisation takes place.—Measures taken to relieve congestion by removing effects in central districts do not diminish its intensity beyond a brief period.—Decentralisation does not relieve congestion unless accompanied by the disposal of industries and the spreading of transport facilities over wider areas.—The causes of congestion of business and traffic are inadequate space about buildings combined with defective highway and street systems.—A city an artificial growth.—Need to regulate that growth.—More regard needs to be paid to natural forces and to securing proper scale between the streets and buildings.—More sunlight and air space in central areas of cities.—Solution of these problems by making comprehensive plans for metropolitan regions.—Such a plan must be based upon a full investigation of all the facts relating to physical, historical, social, and economic conditions.

22. Dr. H. H. Laughlin (Eugenics Record Office, Carnegie Institution).—*Immigration from a Biological Point of View.*

23. Mr. W. L. G. Joerg.—*Human-Use versus Natural Regions, with Special Reference to North America.*

History of the development of the 'natural regions' concept or its equivalent among American geographers. Early interest in subdivision into 'physiographic provinces,' culminating in map of the United States by Fenneman, with extensions into Canada and Mexico by Thayer. Present emphasis on human and economic geography has caused some to raise question of desirability of establishing regions reflecting human element more fully. Appointment of committee of Association of American Geographers to delimit 'geographic provinces' of United States and Canada with this end in view. Analysis of the problem.

24. Mr. O. H. T. Rishbeth. — *Some Geographical Consequences of the Geology of Australia.*

Australia owes its surface-cover to the circumstances of its geological structure, to its age, and to a range of erosional processes appropriate to its historical climatic regimes.—Characteristic of this cover are regional and local

variations repressed within rigid and severe limits.—The surface-cover, important as its influence is upon the development of mineral production, exerts its maximum effect in the control of water-supply.—In few areas of equal extent is man faced more immediately and more permanently with the facts of geological control.—The nature and conditions of water-supply, and consequently of settlement, in Australia offer striking contrasts with those prevailing in such countries as Europe and Canada.—Certain features of social and political development consequent upon these conditions are clearly discernible.

25. Mr. A. Stevens.—*Some Rural Dwellings and Communities of Rural Scotland.*

The environment of the north-west of Scotland: geological; minerals and soil; climatic; vegetable. Permanent habitations in relation to form, materials, site. Temporary habitations: nomadism. The crofter's industry. Site and arrangement of crofter villages. Conditions which determine collection of crofting communities into villages.

SECTION F.
ECONOMIC SCIENCE AND STATISTICS.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 466.)

Thursday, August 7.

1. Presidential Address by Sir William Ashley, Ph.D., on *A Retrospect of Free Trade Doctrine.* (Page 148.)

2. *Business Forecasting:* (*a*) Sir William Beveridge, K.C.B.; (*b*) Mr. R. H. Coates. Discussion opened by Prof. H. Michell.

Friday, August 8.

3. Mr. G. Udny Yule, F.R.S.—*The Population Problem from the Standpoint of the Pearl and Reed Law of Growth.*

The paper is largely of the nature of a review. The argument of Malthus shows that the population on a limited area cannot increase indefinitely in geometric progression, but does not suggest the true form of the law of increase. The 'principles' of Quetelet (*Physique Sociale*, 1835). The work of Verhulst (1838) and the arguments that led him to the 'logistic' formula

$$y = \frac{L}{1 + e^{\frac{\beta - t}{\alpha}}}$$

The recent (1920) independent suggestion of the same formula by Pearl and Reed and their work thereon. The populations of the United States, England and Wales, and France as illustrations. An improved method of calculating the constants and comparison with the method of three ordinates. Questions raised by the form of the curve as to the causes which determine the limit population, and as to the existence of an optimum population.

4. Prof. R. M. MacIver.—*Civilisation and Population.*

5. Sir William Beveridge, K.C.B.—*The Fall of Human Fertility among the European Races and some of its Social Reactions.*

6. Prof. JAMES A. FIELD.—*Eugenic Worth and Economic Value.*

The attempt to dispose of population problems in terms of the limits of gross subsistence seems to overlook the most interesting and some of the most important aspects of the case. It is by no means clear that the ideals professed in formulating broad population policies are quite consistent with the standards which govern our system of economic rewards. The present paper is an attempt to outline an inquiry on this point, and to relate it to the general subject of the standard of living.

Monday, August 11.

7. Prof. A. L. BOWLEY.—*The Economic Outlook in Great Britain.*

The position in 1924 is compared with that in 1914, in respect of population, employment, prices, wages, income, production, and trade. The standard of living is at present stabilised at the pre-war level, though working hours are reduced. Necessary imports are obtained in return for reduced exports. The problem of employment is still to a great extent one of post-war adjustment. In a few years' time the increase in the number of the employable population will be checked. Certain adjustments in distribution of occupations and in relative wages are necessary, but till European affairs are more settled it cannot be foreseen whether increase in external or in internal trade should be the objective. Meanwhile, there is little development in home industry, and it is doubtful whether output can be increased without an extension of the working week, or whether full occupation can be found without reduction in real wages. None of the difficulties envisaged are insuperable, and the adjustments necessary are of a minor character.

8. *Unemployment Prevention and Insurance.*—(*a*) Prof. J. R. COMMONS, (*b*) Mr. BRYCE M. STEWART. Discussion.

Mr. BRYCE M. STEWART.—One of the most significant of the recent experiments in unemployment insurance is that initiated in May 1923 under an agreement between the associations of men's clothing manufacturers in Chicago and the Amalgamated Clothing Workers of America. It is the most pretentious scheme in America, and an outstanding example of unemployment insurance by industry.

The Union acquired control of the allocation of labour in the Chicago market, employing about 35,000 workers, under a preferential agreement signed in 1919.

Anticipating the adoption of unemployment insurance, the Union in 1922 organised a central employment exchange, which plays an important part in the administration of the scheme.

Under the plan each employee contributes $1\frac{1}{2}$ per cent. of his wages and the employer an equal amount. About eighty of the larger firms have individual house funds, but the contributions of the smaller firms are pooled. Employers who give regular employment are encouraged by a provision that when a house fund has accumulated an amount sufficient for the payment of the maximum benefit for two years, the contributions of the house and of the employees shall cease until the fund has been depleted to an amount sufficient for one year's benefit. The joint contributions for the whole industry in the year ended April 30, 1924, totalled slightly over one million dollars.

Administration is vested in four boards of trustees chosen by the employers and the Union. The chairman, Prof. John R. Commons, of Wisconsin University, was appointed by both parties. He presides over all the boards.

Payment of benefit began May 1, 1924. Benefit is paid for part-time unemployment as well as for lay-off, and the waiting period in each case is 44 hours, which is the regular weekly working period. Workers on short time receive benefit for all time lost in excess of four hours in the week, every hour of overtime offsetting one hour of unemployment. The benefits are 40 per cent. of the full-time wages, with \$20 per week as a maximum, but not more than two and one-half weeks' benefit may be paid in either of the two working seasons, and not more than five weeks' benefit in the year.

In the cutting branch of the trade the incidence of unemployment is chiefly upon a group of so-called 'temporary cutters.' They constitute a flying squadron not attached to any house. A special fund has been established to meet the special needs of these employees by using all the contributions of the 'temporary cutters' and one-sixth of the contributions of the permanent cutters. Permanent cutters receive benefits of one-third of the weekly wage instead of 40 per cent. They are limited to five weeks' benefit in the year, and 'temporary cutters' may receive ten weeks' benefit.

The development of the plan is being closely watched by employers and Trade Unions in the United States, and in some degree it has given pause to the demand for a Governmental scheme. The question arises if future development will be in the direction of the co-existence of some such plan of insurance by industry and a Governmental system after the English model.

Discussion opened by Prof. Gilbert E. Jackson.

Tuesday, August 12.

9. Joint Discussion with Section M on *Diminishing Returns in Agriculture.* Paper by Prof. C. R. Fay. Discussion by Sir John Russell, F.R.S., Lord Bledisloe, Sir Henry Rew, Prof. E. Cannan, Mr. R. B. Forrester.

Wednesday, August 13.

10. (*a*) Exhibition of a film illustrating the Marketing of Wheat, explained by Prof. C. R. Fay.

(*b*) Prof. J. E. Boyle.—*The Marketing of Grain.*

SECTION G.—ENGINEERING.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 467.)

Thursday, August 7.

1. Presidential Address by Prof. G. W. O. Howe on *One Hundred Years of Electrical Engineering.* (Page 178.)

2. Sir Henry Thornton.—*Railway Transportation in Canada.*

(1) An opening reference to the part which railway transportation plays in modern industrial and economic life. (2) A picture indicating the condition in which the beginning of the railway era found Canada, contrasted with the situation as it exists to-day. (3) A historical sketch covering the period of railway development in Canada—

(*a*) before confederation; (*b*) the confederation period; (*c*) the balance of the nineteenth century; (*d*) the twentieth century.

(4) A review of the physical evolution of railway transportation in Canada. (5) A review of the features distinguishing railway development in Canada from the development in Europe. (6) The traffic characteristics of Canada from the railway transportation standpoint. (7) A review of the present economic problem as affecting railway transportation in Canada. (8) The probable future tendencies of railway transportation in Canada and elsewhere.

3. Lt.-Col. H. S. Lamb, D.S.O.—*Engineering Problems and Traffic on the Great Lakes.*

A description of the work involved in the development of the Great Lakes system of waterways, including the canals and locks constructed to overcome the two great barriers on this system, namely, Niagara Falls and the St. Mary's Rapids. The general design of the harbours, the type of structures principally

adopted, and the class of materials usually used in the construction of these works. A brief statistical record of the traffic on this international system of waterways.

Friday, August 8.

4. Mr. J. B. Challies (Director of the Water-Power and Reclamation Service).—*Water-Powers of Canada: An Outline of their Extent, Utilisation, and Administration.*

Canada is particularly fortunate in the nature, extent, and location of her power-producing resources. The water-power resources of Canada are widely distributed and of great extent. They are to be found in every province, and are most abundant in the central provinces, where the absence of native coal makes them of special value. Climate and topography are both favourable to the presence of water-powers on a large scale. The rainfall is abundant, the mountain systems are extensive, and the snow-fields of the Rocky Mountains and the uncounted lakes of the Eastern Plateau form vast natural reservoirs. Water-power is indeed one of the principal natural resources of the Dominion, and its development may, without exaggeration, be termed one of the romances of engineering industry.

The modern water-power industry began in Canada about 1895, and has shown a steady and remarkable growth which promises to be even more rapid in the future than in the past. During the last ten years, while the population increased 22 per cent., the developed water-power increased nearly 100 per cent. and its use in industry 245 per cent. The total water-power throughout the Dominion is estimated at over 18,000,000 horse-power, of which 3,227,414 horse-power is now developed and 750,000 additional horse-power is under construction.

The capital invested in water-power development, transmission and distribution has grown from $121,000,000 in 1910 to $688,000,000 in 1923, and the opportunities for further investment in such enterprises are numerous and attractive. Natural resources are abundant, labour conditions are stable, agriculture and manufactures are increasing their yield, and new markets are being developed. The conditions in the central station, pulp and paper, mining and other industries, show their dependence upon water-power development.

The greatest part of the undeveloped water-powers of Canada belong to the Crown, either in the right of the Dominions, as in Alberta, Saskatchewan, Manitoba and the Territories, or in that of the provincial governments, as in the other provinces. The Crown grants issued under the various jurisdictions afford security of tenure and reasonable protection to capital, combined with such extent of control as is considered necessary in the public interest.

In some of the provinces, developments have been made directly by Government agencies; in others, private enterprise is alone responsible for the supply of hydro-electric energy. Each in its own sphere has given beneficial results.

5. Mr. F. A. Gaby (Chief Engineer, Ontario Hydro-Electric Commission).—*The Hydro-Electric Power Commission of Ontario.*

Early conditions which prompted the initiation of 'Hydro.' Public interest leads to Government action. The Commission contracts for its first supply of power. New sources of power supply were soon required. Various hydro systems were formed as circumstances dictated. Transmission network. Financial structure of 'Hydro.' Low rates for 'Hydro' service. Character of service received in rural districts. Rural rates are favourable. The Queenston-Chippawa development. The power developments of the Hydro-Electric Power Commission. The future of 'Hydro' full of promise. Chief sources for more electrical energy. Co-operation required for action respecting the development of the St. Lawrence. An electrical power shortage in prospect. St. Lawrence power is low-cost power.

6. Mr. R. S. Lea.—*Development of St. Lawrence River for Power and Navigation.*

From Lake Ontario level at Prescott to the ocean port of Montreal, a distance of 120 miles, the St. Lawrence River descends in a series of rapids alternating with navigable reaches, through a total height of about 225 ft. About two-

fifths of the fall occurs in the upper half of this stretch, the most of which also happens to form a part of the boundary between Canada and the United States, and along which, therefore, each country has equal rights in the use of the water. Below this, the river is wholly within Canadian territory. Fourteen-foot navigation by means of a system of canals and locks around the rapids has been available for many years. Power has also been developed to the extent of about 350,000 h.p., partly in connection with the canals, but mainly in a few plants, two of large size and recent installation, deriving their power by diverting for themselves a portion of the flow of the river.

The paper refers to certain interesting and unusual characteristics of the river, the volume and variation of the flow under summer and winter conditions, and the action of ice in different forms, the last being generally the governing factor in determining the best method of developing power in the different reaches. It also describes the main features of certain projects recently put forward, either (*a*) for the primary purpose of power development on a scale necessitating the utilisation of the flow of the whole river, with provision for present and future navigation requirements, of (*b*) as a scheme for securing deep-draft navigation sufficient for ocean-going vessels, with the incidental creation of opportunities for power development. The second scheme is a part of a more extensive undertaking, to enable ocean shipping to reach the head of the Great Lakes system. From either point of view the projects are of exceptional magnitude and importance, the minimum ultimate depth proposed for the locks and navigation channels being 30 ft., and the total power when fully developed amounting to from 4,000,000 to 5 000,000 h.p., with individual plants having capacities of from 600,000 to 1,500,000 h.p. Considering that about four-fifths of this power is in Canada, within transmission distance of its largest industrial centres, mining areas, and its two largest cities, it is obviously one of the country's most valuable assets.

7. Joint Discussion with Section A on *Optical Determination of Stress.* Mr. A. L. Kimball.—*Some recent Photoelastic Investigations by means of the Coker method in the United States of America.*

Monday, August 11.

8. Profs. H. F. Moore and T. M. Jasper.—*The Evidence for the Existence of an Endurance Limit in Metals.*

1. The importance of this problem. The study of fatigue phenomena and of various laws of fatigue failure are profoundly affected in their treatment by the existence or the non-existence of an endurance limit. This is an experimental problem.

2. Brief historical summary. This would include the naming of Wöhler and his experimental work; Basquin and his proposed exponential relation; Stromeyer and the thermal evidence for endurance limit; and other people who have discussed the existence of such a limit.

3. The elastic limit idea and its limitations.

4. The inception of extensive investigations of fatigue limits in the United States. In at least two of these investigations the main problem laid out was the securing of direct evidence as to the existence of an endurance limit by means of long-time tests.

5. A very brief summary of machines and test methods used, with reasons.

6. The interpretation of test data of fatigue tests with respect to securing evidence for the existence of an endurance limit.

7. Short-time tests for the fatigue limit and their reliability.

8. Fatigue limits in non-ferrous metals.

9. Correlation between endurance limit and other physical properties of metals.

9. Prof. C. F. Jenkin, C.B.E.—*The Work of the Fatigue Panel of the Aeronautical Research Committee.*

Soon after the War the Aeronautical Research Committee appointed a panel to investigate fatigue in metals. This work has been carried on vigorously

ever since, and a great many interesting facts have been discovered, though the fundamental problem—what the real cause and nature of fatigue failure may be—has not yet been solved.

The work of the panel includes investigation on the following subjects: The existence of a finite fatigue limit; the mathematical explanation of how a fatigue crack extends; the nature of elastic hysteresis; phase changes in the metal; the relations between the directions of the principal stresses, the crystal axes and the plane of the fatigue failure; the effects of temperature on the fatigue limit; the action of fatigue at points of stress concentration; fatigue in single crystals; fatigue in amorphous material; the strengthening of metal by fatigue, and many others.

10. Prof. F. C. Lea.—*The Effect of High Temperature on the Range of Repetition Stress for Steels.*

The apparatus used in connection with the Haigh repetition stress machine is briefly described. The endurance range for equal compressive and tensile stresses and for unequal ranges of stress at temperatures varying from 0° C. to 800° C. are given. The phenomenon of creep during statical tests and also during repetition tests is discussed. The fatigue range, for 10 million repetitions, at temperatures as high as 500° C., for equal tensile and compressive stresses, is shown to be higher than at ordinary temperatures; the strength of these temperatures under a statical applied stress is shown to be very low. For unequal stresses it is shown that creep may continue for very many million repetitions, and afterwards the fracture is a 'fatigue' fracture.

11. Messrs. H. F. Gough and H. J. Tapsell.—*Some Comparative Fatigue Tests.*

12. Mr. C. E. Stromeyer.—*Torsion Fatigue Hysteresis.*

Tuesday, August 12.

13. Prof. T. M. Jasper.—*Measurement of Quenching Stresses in Steel.*

14. Prof. H. P. Philpot.—*The Dimensional Problem and Significance of the Notched Bar Test.*

The paper deals with experiments made with the object of finding the type of equation connecting the energy absorbed in the notched bar impact test with the dimensions of the test piece. The test piece is tested in the single-blow pendulum machine and is notched on one side; it is bent by the blow away from the notch, which is set at the level of the top of the vice. The notches used were of the form adopted by the Royal Air Force, and subsequently standardised by the British Engineering Standards Association. The test pieces were all cut from the same bar of heat-treated nickel-chrome steel. The breadth of the test piece b, the thickness behind the notch t, and the distance l of the striking edge of the hammer above the notch, were varied one at a time, giving 19 variations of these three dimensions, and each variation was represented by a number of tests. The equation derived is of the form: $\textit{Energy absorbed} = c.b.t.\left(\frac{t^2}{l^2}+m\right).(l+n)$, where c, m and n are constants. This equation is shown to be of rational form provided that c has the dimensions of a stress intensity, m is a ratio and n is a length. The significance of the test is discussed.

15. Report of Committee on *Complex Stress Distributions in Engineering Materials.*

Wednesday, August 13.

16. Mr. F. A. Dallyn.—*The Engineer and Public Health.*

The writer attempts to divide the group of activities now relegated to Public Health organisations for administration into two classes, (1) those having to do with research and endeavour in the field of hygiene and nutrition, (2) those having to do with specific sanitation and the supervision of public water supplies, milk supplies, sewerage and sewage disposal, stream protection, garbage collection and disposal, and Municipal sanitation generally, including such projects as fly and mosquito control, rodent extermination, delousing stations, &c., and suggests that much of the work of the latter division is of an engineering nature, and could with advantage be left to the direction of engineers and biologists, releasing the medical personnel for their distinctive field, and possibly freeing the public mind of the notion that Public Health is necessarily a medical science.

17. Mr. J. D. Watson.—*The Part Bio-aeration may yet Play in Disposal of Sewage.*

18. Mr. E. A. Watson.—*Cobalt Magnet Steels.*

The paper, intended as a general review of the position at the present time, is divided into three sections :

1. Historical, traces the development of the steels, and describes the present position of the industry, and gives notes as to its future prospects.

2. Describes the various steels available, giving data of their composition and magnetic properties. It traces the effect of cobalt on magnetic properties of a given series of steels, and gives data as to heat treatment.

3. Gives a brief account of the economic factors governing the application of cobalt magnet steels, with data showing the conditions under which the use of a cobalt steel is economically justifiable

19. Mr. R. S. Whipple.—*Some new Recording Instruments.*

20. Mr. A. E. Wynn.—*An Economical Design for Arch Centres.*

The centring design for a two-ribbed concrete arch bridge of 200 ft. span and 40 ft. total rise from river bed to crown, built at Pulaski, N.Y., in 1922, shows some interesting features, in that short lengths and small sizes of timber were used, necessitated by the local available supply, in the use of spikes instead of bolts and because of the high stresses allowed in the timbers.

Three-post bents set on concrete piers in the river supported each rib, the posts being 6 in. by 6 in., in three lengths of 12 ft. ; between the posts were 6 in. by 6 in. caps longitudinally and transverse. The top caps were 6 in. or 8 in. by 12 in., supporting 3 in. by 12 in. stringers, 12 in. apart, cut to curvature, and $\frac{7}{8}$ in. by 6 in. t and g lagging.

All timbers were long leaf yellow pine. The bents were so spaced longitudinally that all members were stressed up to the maximum allowable of 2,000 lb. per sq. in. in bending and 800 lb. per sq. in. in bearing.

No hardwood wedges were used between posts and caps except for one set used in adjusting and lowering the centring.

The posts carried 10 to 13 tons apiece, but the bite in the caps did not amount to $\frac{1}{32}$ in. each, the total deflection of the crown during pouring being only $\frac{1}{4}$ in.

All bracing was 2 in. by 6 in., spiked into the posts with 20d spikes, no bolts being used anywhere. This was considered more effective in adding to the stiffness and was a saving in cost and time. The centring was erected in fifteen days and stripped in four days. The stripping was done by first passing ropes around the stringers and lagging, tying them up to the ribs, then pulling over the bents bodily on to the ice and finally dropping the suspended stringers and lagging. The timber breakage was negligible and the cost was exceedingly

low, only three dollars per thousand board feet of lumber, which included piling up on the river bank.

The cost of erecting and centring was also low, namely, 25 dollars per thousand board feet of lumber, with carpenters at 90 cents per hour and labourers at 50 cents per hour.

The design showed that it is economical to the bridge contractor to use small-size timbers, even for large centres, because they are easy to handle, have just as much salvage value as the larger sizes usually used, and are more readily adapted to smaller bridges, so that they can be used several times over and under any conditions.

SECTION H.—ANTHROPOLOGY.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 467.)

Thursday, August 7.

1. Dr. A. C. Haddon, F.R.S.—*A Suggested Arrangement of the Races of Man.*

The present communication is a suggestion for an arrangement of mankind based on certain physical characters, geographical distribution, and partially on relative antiquity. Existing well-marked races in many cases appear to be the latest expressions of divergent evolution, and we must admit that specialisation may occur at various levels of evolution. It is assumed that primitive man did not possess features that characterise the adult higher apes, and that in some of the 'lower' races their simian resemblances are due to convergence. Thus it is surmised that there was an undifferentiated primitive human stock from which divergencies have continually arisen. If we place in a triple column the gradations of the form of the hair, pigmentation, and the breadth of the nose of dolichocephals we find that the ulotrichous darkly pigmented and very platyrrhine peoples are to be found only to the south of the Himalayas and other ranges along that axis. The same applies to the curly-haired pre-Dravidians. We can, so to speak, 'draw off' from the column at various levels stocks which have a gradual straightening of the hair, less pigmentation and narrower noses, till we come to the somewhat broader-headed Nordics at the uppermost or northern end of the triple column. The brachycephals who developed in the highlands of Western Asia formed the 'Alpine' varieties of leucoderms, while those who developed in the highlands of Eastern Asia were predominantly xanthodermic, and acquired other distinctive characters; from these two main groups practically all the brachycephals now found outside these areas can be derived.

2. Mr. Charles Hill-Tout.—*New Trends in Anthropology.*

The author aims to show in this paper that our earlier conceptions of the skull characters of primitive man were founded upon misleading data.

That instead of instituting comparisons of human skulls with those of mature anthropoids, the comparison should be made with those of immature apes, which by the biogenetic law must represent more closely the ancestral type.

He further points out that a comparison of the skulls of young apes with those of the young Neanderthal man, and both with those of modern children, reveals this ancestral type, and shows that when the problem is approached in this way the conclusion is forced upon us, contrary to what has been generally held, that the anthropoids and not man have departed most from the ancestral type in respect of skull characters, man himself having retained very closely the skull-form of the ancestor common to both branches of the Primates; and that in Eoanthropus we see that ancestral form best typified.

3. Presidential Address by Dr. F. C. Shrubsall on *Health and Physique through the Centuries.* (Page 190.)

4. Dr. C. Wissler.—*The Segregation of Racial Characters in a Population.*

The usual way of comprehending a racial group is by a cluster of anatomical characters. The attempt has always been made to deal with these as wholes, but when attention is fixed upon a single character and its distribution followed throughout a population, or even over the world, the basic nature of the phenomena is revealed. According to the old assumption, a population may be expected to become strictly uniform in course of time. Yet when any character, as colour of eye, hair, &c., is regarded, it is found not to be uniformly distributed, but segregated. Further, it can be shown that this segregation tends to take the same form in all cases. This form, again, is in its general character similar to the distribution forms for culture traits. It follows, then, that the diffusion of anthropological characters is of one general type, whether the traits be cultural or somatic. Somatic diffusion, or the spread of a character in a population, is, therefore, as much a matter of distribution as of morphology. This has an important methodological bearing upon the problem of morphological parallelism in human types versus single origin. This problem is just as pressing as in the case of culture, and cannot be solved by the study of structure alone.

5. Mr. T. Wingate Todd.—*The Relation of Industry and Social Conditions to Cranial Types in Cleveland.*

The only individuals whose cranial capacity can be completely studied are those social ineffectives who have so completely failed in life that they are ultimately found in the dissecting-room. Among these people we have been able to segregate four types of male white crania upon a basis, not of cephalic index or thickness, but of relation of capacity to linear dimensions. The proportional numbers of these types in the dissecting-room population vary from year to year, so that the average cranial capacity fluctuates from year to year. In periods of depression, 1919 and 1921 for example, the dissecting-room population is swelled by the addition of large-brained men with well-filled crania. In years of prosperity like 1918 the big-brained people do not appear, but the population is composed of smaller-brained folk with ill-filled crania. The amount of brain contained in any cranium influences contours more than linear dimensions.

6. Dr. T. Ashby.—*Recent Discoveries in Italy.*

7. Dr. T. Ashby.—*The Roman Road System as a means for the Spread of Roman Military Power, Trade, and Civilisation.*

Friday, August 8.

8. Mr. H. Balfour.—*The Art of Stencilling in the Fiji Islands and the Question of its Origin.*

9. Dr. Alexander Goldenweiser.—*The Historical School of Ethnology in America.*

The distinctive traits of the 'American School' can be best seen against the background of two other schools : (1) the classical evolutionary theory with its tenets of psychic unity, environmental similarity and organic determinism of cultural development through uniform, gradual and progressive stages ; and (2) the diffusionist theory (in Graebner's version), with its quantitative and qualitative criteria of similarity, its mechanical juxtaposition of cultural features, its disregard of time and space, and its hypothetical culture waves and districts.

As contrasted with these, the American School accepts the two principles of independent development of cultural features (creativeness), and of diffusion of such features through historic contact, but it uses them not as universal principles of interpretation but as heuristic tools.

The theoretical position of the American School is best illustrated by the

concept of culture areas which is both objective and psychological, both realistically historical and critical in its evaluation of the alternative principles of interpretation of cultural features.

Other contributions of the American School to the study of primitive cultures are the linguistic and statistical methods and the concepts of convergence and pattern.

10. Mr. W. D. Wallis.—*Diffusion as a Criterion of Age.*

The identification of extent of distribution of a trait with age of the trait cannot be accepted. When one trait displaces another the newer trait is the more widely distributed. The rapidity of diffusion differs with various traits. History shows that the relative distribution of culture traits differs from century to century, as notably in the Mediterranean area. Only at a chosen point in the time perspective is relative distribution an index to relative age. Traits do not spread equally in all directions, hence place of origin seldom remains the centre of distribution. Neither is the area of intensive development always the area of origin. A law regarding the distribution of traits in primitive culture can be checked only by history, not by studying cultures of which the historical development is unknown.

Conclusion: Comparative distribution is not evidence of comparative age. The tendency to spread differs with traits, with culture areas, and with historical epochs.

11. Prof. H. J. Rose.—*The Bride of Hades.*

Why is death so often equated with marriage in Greece? This is true not only of references in literature (as in Sophocles' *Antigone*) but of cult (water-jar, for nuptial bath, on tombs of virgins), and has parallels elsewhere (as in the Rumanian ritual for the burial of an unmarried girl). It is not a case of Todtenhochzeit, which does not seem to have been a Greek custom at any date; the sacrifice of Polyxena is not an instance.

Compare (1) the common equating of human fertility with that of the earth, (2) the myth of the marriage of Persephone to Hades, (3) ritual, such as that of Kybele, the Roman Fordicidia, and the cult of the Eumenides at Sikyon, in which something or someone capable of being fertile is prevented from using his own fertility for the normal purposes in order that it may be given to a fertility-power. The virgin's potential fertility is regarded as going to increase the fertility of earth or of the underworld powers. This naturally finds expression in the metaphor of her marriage.

It is possible that this led to sacrifice of virgins in early times. Mythical and historical examples of a girl being sacrificed to get, not fertility, but its congener, luck in warfare, &c., were given.

12. Mrs. Ruth Fulton Benedict.—*Religious Complexes of the North American Indians.*

All over North America, except in the one interior region of the south-west pueblos, religion was planted squarely upon the idea and practice of the vision. During this psychic experience the manitou or guardian spirit was made known, along with taboos, songs, privileges, and immunities of various sorts. In each diverse region of North America this basic Indian religious trait has made the most intimate associations with other interests of the cultural background: puberty initiation, hereditary rank, hunting, tribal warfare, clan organisation, and the like. In no case is the origin of one associated trait to be looked for in the other, since both have independent distributions and are found unassociated with one another. Necessarily, also, these complexes cannot be so old as the basic continent-wide concepts they embody. The cultural connotations of religion, therefore, are not stable over great lapses of time, nor is religion genetically related to them; they are local associations of ideas which are essentially fortuitous.

13. Mrs. Erna Gunther Spier.—*An Analysis of the Ceremony of the First Salmon on the Pacific Coast.*

14. Col. E. Laidler.—*Some Ojibwa Nature Stories.*

15. Mr. Warren K. Moorehead.—*The Red Paint People of Maine.*

This paper presents explorations among the graves of a strictly prehistoric culture in central Maine; 440 of these graves have been examined, and eight types or forms in stone artifacts persist. The culture is not Algonkin, nor does it appear to be related to any known Indian culture of the United States. There is a slight similarity between it and that of the Eskimo. A characteristic feature is that nearly every grave contains a large quantity of powdered hematite, apparently brought from the natural outcrops of iron ore found near the head of the Piscataquis river in north-central Maine.

16. Dr. A. Hrdlicka.—*The Antiquity of Man in America in the Light of Recent Discoveries.*

During recent years research on Man's Antiquity in America has been greatly stimulated by a number of accidental finds of human remains in a state of fossilisation, or under circumstances which more or less strongly suggested geologic antiquity. Such finds have been reported from Ecuador, the Valley of Mexico and various parts of the United States, especially California. The most remarkable of them to date (May 1924) is doubtless the discovery of six human skeletons beneath 19 to 23 feet of sand and silt in the outskirts of Los Angeles. This last-named discovery was made accidentally during the construction of an outlet for a sewer, and, thanks to the authorities of the local museum and especially to Dr. John C. Merriam, President of the Carnegie Institution, they were subjected from the start to a careful scientific scrutiny. A preliminary report on this important find was made before the National Academy of Sciences at its April meeting in Washington.

The antiquity of the specimens that form the subject of this paper differs, and in some instances, particularly that of the Los Angeles find, is doubtless considerable. But according to all indications it is still not a geological antiquity, nor an age measurable in tens of thousands, but rather to be estimated in thousands of years.

17. Joint Discussion with Section E on the subject of Prof. J. W. Gregory's Address.

18. Mr. W. J. Wintemberg.—*A Tentative Characterisation of Iroquoian Cultures in Ontario and Quebec, as determined from Archæological Remains.*

We know from historical sources that the Hurontario peninsula was occupied by the following tribes and tribal group of the Iroquoian stock : The Tionontati or Tobacco Nation Indians, the Hurons, and the Attiwandarons or Neutrals. There are many indications that the country between Lake Simcoe and Montreal also was occupied by people of Iroquoian stock, but we have no definite historical information as to what tribes were represented. A comparison of the artifacts from known Huron sites and from Onondaga sites in New York State with those from Iroquoian sites of this region, however, indicates that this area was probably occupied by the Hurons and Onondaga. Some post-European sites in the region between the Grand River and the Niagara frontier are probably referable to Seneca rather than to Neutral occupation, as is generally supposed. Certain features of the material culture of most of the Iroquoian people inhabiting Ontario are sufficiently characteristic to differentiate the culture of one group from that of another. Archæological evidences, furthermore, seem to indicate that the culture of at least one group is divisible into four stages or chronological periods.

19. Mr. Guy E. Rhoades.—*Composition in the Art of the North-West Coast Indians.*

The synthesis of design units in the conventional decorative art of the Indians of the North Pacific Coast has already been noticed. The reason for its development would seem to be found in the technique of application; and this involves the question of priority in the origin of painting and carving.

It would seem that the whole of the North-West Coast conventional art is essentially a painting art. The tapering of the lines of one unit towards the points of junction with another unit would seem to be most easily and naturally produced by a brush technique, whereas there seems no natural means for its development in carving. The construction of painted and carved designs is essentially the same; and it would seem that the latter is a development from the former.

Carving, on account of its wide distribution, is supposed to have been the first art developed; but this is probably true only of realistic representations and not of the conventional art.

20. Dr. H. M. Ami.—*Recent Discoveries in Prehistory.*

Monday, August 11.

21. Mr. Harlan I. Smith.—*Trephined Aboriginal Skulls from British Columbia and Washington.*

Two recently discovered specimens extend our knowledge of the distribution of trephined aboriginal skulls, and also of a rare narrow type of skull in British Columbia and Washington.

These skulls were found in the large shell-heap along the west side of Boundary Bay, about twenty miles to the south of Vancouver. One of the skulls is of a rare narrow type found in the Eburne shell-heap, the other of a wide type common to the region in both prehistoric and modern times.

These specimens were collected for the Victoria Memorial Museum, Ottawa—the National Museum of Canada.

The antiquity of this trephining and the two types of skulls is considerable. The heap at Eburne is known to have existed in 1497 or earlier, as in 1898 we counted over 400 rings of annual growth on a stump standing on the heap. As the outer part of the stump had been burned there must have been more rings, indicating a greater age. There were many large trees and stumps on the heap. The skeletons were below layers continuing unbroken under these stumps.

22. Mr. L. H. Dudley Buxton.—*Skulls from the Valley of Mexico.*

The skulls under consideration include a series of 'Toltec' skulls excavated at Azcapotzalco, near Mexico City, and two series in the Museum in Mexico City which are said to be Aztec and Tarahumare respectively. These two latter series resemble one another closely, but the former show a greater degree of mixture. The Toltec skulls differ from them in many points, and it seems impossible that they can belong to the same people. On other grounds it seems probable that the Toltecs are of Nahua affinities, and therefore should be of similar physique, although this point is much disputed by archæologists. The Toltec skulls seem to be more closely allied to the Maya type. The same type, however, occurs in ancient crania excavated in Mexico by Hamy, and it is possible that there may have survived in the Valley of Mexico an older type akin to the people of the south, and differing from the people of the north. If, however, the remains at Azcapotzalco are accepted as genuine remains of the Toltec people, then the conclusion seems necessary that the latter tribe were physically at least akin to the Mayas.

23. Prof. C. G. Seligman, F.R.S.—*A Pseudo-Mongolian Type in Central Africa.*

24. Miss Margaret Mead.—*Rank in Polynesia.*

The concept of rank is found throughout the social organisation of the Polynesian islands, although there are many important differences in the way this widely distributed idea has been modified and re-interpreted. An analysis of the idea of rank as found in Samoa, Hawaii, and New Zealand shows that, while this idea of a sacred hereditary group, protected by a multitude of taboos,

is found in each of these cultures, there is a different cultural emphasis. The governmental prerogatives of the aristocracy have been almost entirely absorbed into a democratic system in Samoa; in Hawaii, elaboration of the idea of rank resulted in rigid lines of demarcation through every phase of Hawaiian society, and has developed among the Maori a particularly coherent and integrated social system based upon the mutual dependence of more privileged and less privileged.

25. Joint Discussion with Section J (*q.v.*) on *Racial Mental Differences.* (Page 439.)

Tuesday, August 12.

26. Dr. Laughlin.—*Some of the Racial Characteristics Emerging from America's Study of her Immigrants.*

27. Mr. D. Jenness.—*The Ancient Education of a Carrier Indian.*

28. Mr. T. F. McIlwraith.—*Some Aspects of the Potlatch in Bella Coola.*

In Bella Coola no ceremonial event, such as a marriage, a mourning ceremony, a bestowal of names, or a dance, is performed except in the presence of spectators. To the Indian it would be unthinkable for the host to allow such spectators to depart without giving to each a present, i.e. without a potlatch. Each recipient becomes a legal witness of the ceremony; thus the essence of the potlatch is a means of validation.

It has also a social significance. The value of each present is carefully remembered, and it is incumbent on the recipient to return at least an equivalent at some future potlatch. A man's personal prestige and social importance increases if he repay promptly with heavy interest, whereas, should he fail to do so, his influence is lessened. Thus a man's status in the community virtually depends on the number and size of the potlatches which he has given.

29. Dr. E. Sapir.—*The Privilege Concept among the Nootka Indians.*

30. Prof. W. K. Gregory and Mr. M. Kellman.—*The Dentition of Dryopithecus and the Origin of Man.*

Parts of three lower jaws of fossil anthropoids of the genus *Dryopithecus* have recently been discovered in the Siwaliks by Barnum Brown, of the American Museum of Natural History, New York. The fossils include a nearly complete forepart of the jaw, and two left halves, with the cheek teeth beautifully preserved in both. They were found in three successive horizons of the Lower and Middle Siwaliks, and the series as a whole reveals a progressive modification of the premolars in the direction of the later anthropoids. The new specimens thus afford a welcome addition to knowledge of the Siwaliks anthropoids described some years ago by Pilgrim, of the Indian Survey. The '*Dryopithecus* crown pattern' of the lower molars is fully expressed in all the Siwaliks anthropoids, and has been traced, with detailed modifications, not only into the molar crown patterns of each of the existing anthropoids, but also into those of primitive human types. The anterior premolar of *Dryopithecus* is laterally compressed, but the homologous tooth in chimpanzees varies from a compressed form, recalling that of *Dryopithecus*, to an almost human bicuspid stage.

These facts, in the light of cumulative anatomical evidence for the relatively close relationship of man with the existing anthropoids, not only afford strong support for Darwin's view that man is an offshoot from the anthropoid stem, but tend to indicate that the distinctively human modifications of the dentition took place after the Middle Miocene.

31. Mr. C. M. Barbeau.—*The Crests of a Tsimshian Family: a Study in Native Heraldry.*

32. Prof. F. G. Speck.—*Some Tribal Boundaries of the Montagnais and Naskapi of the Labrador Peninsula.*

33. Mr. B. Oetteking.—*The Santa Barbara Skeletal Remains.*

Wednesday, August 13.

34. Mr. H. Balfour.—*The Welfare of Primitive Peoples.*

35. Dr. Alex. Low.—*Processes of Growth in Infants.*

A preliminary study of the results of anthropometric examination of infants to discover how far sex, growth, and environment influence physical characters. Data pertaining to school children are available, but beyond records of weight and length at birth, data as regards children of pre-school age are very meagre. Our knowledge of growth as determined by the physical measurement of infants is mostly based on single measurements of groups of infants, so that there is no way of estimating the degree of variation in the *same* individuals at different periods of their growth.

Five hundred and forty infants have been examined at birth, and detailed measurements and individual histories recorded. An effort is being made to re-examine as many as possible at intervals of six months for at least two years. Re-examination is slow, and some years must elapse before sufficient remeasurements of the same individual children can be obtained to enable conclusions to be formulated.

36. Miss R. M. Fleming.—*The Influence on Growth of some Race and Sex Characters.*

37. Mr. L. H. Dudley Buxton.—*Physical Observations on Navajo Children.*

The observations were made on the Navajo Reservation in Arizona and at Albuquerque in New Mexico. Stature, sitting height, weight and age have been selected for special consideration. English school children have been used as a control. The methods used are of the simple biometric type, and special attention has been paid to the construction of Regression Coefficients and the comparison of observed and calculated results.

The conclusions reached have been that at least for the earlier ages a good regression table calculated from a large number of English children (a number of which tables have now been published) works almost as well for the Indian children, if we take the mean values, as one calculated from observations on Indian children. The differences, especially in weight, are, however, of interest when a consideration is made of the different social and environmental conditions under which the children live.

38. Miss Isabel Gordon.—*Cultural Stability among the Mountain Whites of Tennessee.*

A study of the modifications in the life of an English-speaking community due to geographical isolation.

The geographical and historical causes of this isolation were briefly described. The region was settled between one hundred and one hundred and forty years ago. The methods of agriculture, tanning of leather, spinning, weaving, cooking, &c., which the early settlers brought with them continued practically unchanged until very recent years. After a consideration of these and other aspects of the culture which have remained *stable* some of the changes which may be traced to isolation will be discussed.

While the general culture of the whole of the southern Appalachian region is the same, we do find a certain amount of differentiation between the various valleys and coves. Some of these differences will be described and the reasons for them indicated.

A brief account was given of a group of folk-tales collected in these mountains and their relation to European folk-tales.

39. *Report on the 'White Indians' brought by Mr. R. O. Marsh from the Isthmus of Darien.*

By the courtesy of the *Toronto Star* and of Mr. R. O. Marsh, Dr. F. C. Shrubsall, Dr. A. C. Haddon and Mr. L. H. Dudley Buxton, assisted by Dr. Catteley, ophthalmologist to the Ogdensburg Hospital (New York State), had an opportunity of examining these Indians at Prescot, Ont. They included three children who have been described as white Indians—two boys and a girl—the parents (brown) of the girl, and two San Blas Indians. The white subjects were very sensitive to light, and their vision subnormal. They showed rapid lateral nystagmus. The colour of the irides was greyish-violet. Examined by the ophthalmoscope choroidal pigmentation was markedly deficient. The hair was light golden and straight. The skin was as light as that of a northern European with the same rosy tint. It showed distinctly yellow-brown freckles and blotches on the exposed parts. The conclusion is that the so-called 'white' characteristics are due to albinism and are of no racial significance.

SECTION I.—PHYSIOLOGY.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 468.)

Thursday, August 7.

1. Presidential Address by Dr. H. H. Dale, C.B.E., F.R.S., on *Progress and Prospects in Chemotherapy*. (Page 211.)

2. Prof. A. B. Macallum, F.R.S.—*On the Absorption of Organic Colloids by the Intestinal Mucosa.*

Except in the case of fats and soaps, little has been determined regarding the mode of absorption of organic colloids by the epithelial cells of the intestinal mucosa and the manner of transfer through the cells to the interior of the villi. This is due to the fact that there are no microchemical stains which will localise the absorbed proteins.

Guinea-pigs and rabbits were fed with fresh undiluted egg-yolk for a day or more, after they had been kept without food for 24-48 hours. The yolk is introduced into the œsophagus by a pipette, and as much as 10 c.c. may thus be given three times a day. Thus given, the yolk, practically unaffected by gastric digestion, reaches the intestine and immediately comes in contact with the tips of the villi, the cells of which begin at once to take it up and transfer it to the underlying tissues; but as the latter do not absorb it as fast as the cells deliver it to them, an accumulation of it occurs at their bases which at the end of twenty-four hours is so great that the epithelial layer at the tips is 'ballooned' or raised to a height several times the long diameter of the normal cells above the 'basement membrane,' and the cells are flattened by the pressure to which they are subjected internally. They continue to absorb it, and at the end of forty-eight hours or more the 'balloons' at the tips of all the villi are ruptured and the contents escape into the intestinal cavity, but before this rupture occurs some of the absorbed material is transferred through the adenoid tissue to the lacteals, which are in consequence greatly distended and contents contain some at least of the proteins as well as the fats of the absorbed yolk. A careful examination of the epithelial cells, both in the fresh and in the fixed condition, during the early stages of this absorption makes it evident that in this absorption the cells are active, not passive, elements. The contents of the yolk spherules, which are all disintegrated, come into intimate contact with the free borders of the cells; the proteins dissolve in the protoplasmic

processes which also take up the fat particles, which are almost of ultramicroscopic size, and both proteins and fats are transferred through the pores of the basement membrane to the interior of each cell. Here the cytoplasm dissolves the proteins or enters into intimate relations with them, and they diffuse towards the base of the cell, where they are set free in a concentrated form with such amounts of the lipoids as are transferred there in a micellar condition. In this passage through the cell the proteins may lag behind the lipoids, and as a result one may find in certain of the cells, particularly in those at the sides of the tips of the villi, spherules of protein, of 3-4 μ in diameter, free from lipoids, lying in cavities of the cytoplasm, which is, however, setting free proteins and lipoids at the basal end of the cell.

The 'ballooning' of the epithelial covering of the villi and the great distention of the lacteals indicate that in the transfer of the proteins and the lipoids to the lacteals the epithelial cells and the cells of the underlying adenoid tissue work against a pressure which cannot be classified as osmotic pressure as generally understood. Probably the force known as intrinsic pressure plays a very important part in this transfer, but the phenomena involved recall those which are manifested in the passage of hydrogen through palladium and platinum. This compels recasting of the conception of the osmotic forces concerned in the passage of solutes and colloids through membranes.

The interpretation of these results has a bearing on the transfer of proteins and lipoids from the blood to the tissues, and on the diffusion of these through and from the cells of the tissues. They also explain anaphylaxis of intestinal origin.

3. Prof. W. B. Cannon and Dr. A. Querido.—*The Rôle of Adrenal Secretion in the Chemical Control of Body Temperature.*

Previous experiments have shown that injection of adrenalin and also increased adrenal secretion accelerate the oxidative processes in the body. Evidence has been obtained that adrenal secretion is increased when there is liability of lowered temperature by heat loss. When the same liability is presented to animals with intact, or, on the other hand, with inactivated adrenal glands, shivering is prominent in the latter and not in the former. When the liability is established for man the metabolism may be increased as much as 25 per cent. without shivering. The conclusion is drawn that the body has two lines of defence against cooling: (1) a true chemical calorigenic agent, first called into action, and (2) shivering. The evidence confirms the views of Voit and of Rubner, and offers an explanation for the chemical calorigenesis, apart from muscular movement, which they argued for.

4. Prof. G. N. Stewart and Prof. J. M. Rogoff.—*The Adrenals and Metabolism.*

The consequences of partial and complete adrenalectomy in different animal groups and of elimination of the medulla only will be compared. Possible effects of epinephrin discharged from the adrenals upon the metabolism, especially in connection with the alleged reciprocal relationship of the pancreas and the chromaphil tissue, will be discussed. Fallacies underlying the supposed marked diminution in the tolerance of adrenalectomised animals for certain poisons, particularly morphine, will be pointed out.

5. Prof. A. T. Cameron, Dr. T. Ingvaldsen, and Dr. J. Carmichael.—*The Activity of Iodothyroglobulin and its Digest-Fractions as compared with Thyroid.*

The test used was the effect on young white rats, as regards decrease in growth-rate and development of organ-hypertrophy. Comparison was made rigidly on rats of the same sex and litter, using desiccated thyroid as a control, and basing dosage on iodine content. Thyroglobulin showed not quite as much activity as thyroid. NaOH, pepsin, and trypsin digests were tested. The NaOH filtrate showed no activity, the remaining fractions (soluble and insoluble) showed activity of the same order as thyroid. (Di-iodo-tyrosine was inactive.)

The results are considered to support the view that the internal secretion of the thyroid is a compound of thyroxin with some other radical which considerably increases its activity.

6. Prof. H. C. Bazett.—*Experimental Aortic Regurgitation in Animals.*

X-rays and electrocardiographs and also some blood pressure readings have been taken on dogs with chronic aortic regurgitation. The outstanding result has been that after the operation the heart shadow is diminished in size. Where dilatation has been seen the animal has died immediately. There appears to be a diminution in the size of the right ventricle, with only a relatively slight increase in the left. Within a few weeks the heart is definitely larger, but at death there has been only slight hypertrophy, even when the animal has exercised daily for a month. The appearance has been more that of a chronic mild dilatation with lengthening of the fibres. No striking electrocardiographic changes were found.

Systolic blood pressure in the femoral above those of the brachial or carotid were readily obtained. Animal experiments and some with a schema suggest that this is due to the kinetic energy of the blood, which is greater in the lower extremities than in the upper.

7. Dr. R. Dominguez.—*Observations by a Clinical Method over long periods on the Blood Pressure of Rabbits under various Physiological and Pathological Conditions.*

The determination of the blood pressure in the intact animal is recognised to be important. The ideal method should be simple in application, should involve the least manipulation of the animal, and should allow frequent and numerous observations. These requirements are met by Van Leersum's method, as employed by us. Rabbits are used. The carotid artery is exposed, dissected, and then surrounded by a cutaneous flap. In this way a loop is made, around which a cuff, connected to a Riva-Rocci manometer, is applied, and then readings obtained by palpation. The animal is placed in a box and its head raised by means of a ring so as to expose the loop. Observations have been made on excitement, struggle, digestion, inanition for reasonable intervals, temperature, copulation, small doses of morphin, such pathological conditions as naturally arise in a laboratory, and the effect of double adrenalectomy. I have been unable to confirm the alleged 'hypertension' of experimental cholesteatosis.

8. Dr. A. C. Ivy, Dr. R. K. S. Lim, and Dr. J. E. McCarthy.—*The Genesis of the Second Phase of Gastric Secretion.*

The second phase of gastric secretion may be further subdivided into gastric (Pavlov) and intestinal phases (Pavlov, Ivy).

Gastric Phase.—We have found, contrary to Pavlov, that local mechanical stimulation of the stomach causes secretion. The effective stimulus is a sudden distension, or, if slowly induced, a distension which eventually induces motility, such as occurs after a more rapid inflation. The mechanical effect is abolished by fat in the intestine, and to a less degree by fat in the stomach; it is completely prevented by atropine (subcutaneously). Since an increase of 200 c.c. in the gastric volume causes secretion, it was possible that previous observations on chemical or secretagogue stimulation might have been due to the mechanical factor alone, especially as the quantities employed were rarely less than this amount. Applications of raw meat, meat juice, glucose, B-alanine, and histamine in 20-c.c. amounts confirm the existence of a chemical factor.

Intestinal Phase.—In a dog with the whole stomach formed into a pouch (the vagi being cut) and the duodenum anastomosed to the esophagus, the feeding with water, milk, meat, bread, B-alanine or histamine (which naturally proceeds directly into the intestine), all cause secretion in the isolated stomach. Atropine and fat inhibit this secretion.

Mechanism.—Transfusion of fed blood to unfed Pavlov pouch dogs has no influence on gastric secretion. In similar animals, cross-circulated by

anastomosing the carotids, feeding of either one of the pair, two or three days after the union, the animals being otherwise normal (conscious), produced no gastric response in the other. This confirms earlier observations (but under anæsthesia) carried out on cats (Lim). It affords no evidence of a hormone (Edkins) mechanism.

We suggest that the mechanism in all cases might be a primary local vascular change—i.e., increase of blood flow in the cœliac stem. The evidence—viz., increased temperature of the stomach, increased volume of the spleen when the stomach is distended, increased volume of the intestine when another segment is dilated—is incomplete, but is in part supported by the stromuhr observations of Burton-Opitz.

9. Prof. F. H. Scott.—*Respiratory Variation of the Arterial Blood Pressure.*

10. Popular Lecture by Prof. J. C. Drummond on *Cod-liver Oil.*

Friday, August 8.

11. Joint Discussion with Section J (*q.v.*) on *Physiological and Psychological Factors of Muscular Efficiency in Industry.* (Page 436.)

12. Prof. H. B. Speakman and Mr. A. H. Gee.—*The Influence of Metallic Chlorides on the Growth and Metabolism of Yeast.*

Yeast cells are able to grow and to ferment sugar in wort containing up to 10 per cent. of salt. With increasing concentrations of salt there is a progressive inhibition of cell division, with no growth stimulation even in very dilute solutions as is the case when a synthetic medium is used. If a sufficiently small number of cells are used as inoculam the maximum rate of gas production is stimulated by low salt concentrations, suggesting that this stimulating influence is only exerted on those cells produced in the medium.

The ratio between yeast crop and sugar fermented changes with the salt concentration, showing that the inhibition of growth and fermenting capacity are independent. The weight of CO_2 produced per gram of sugar utilised diminishes as the salt concentration increases, an indication of abnormal physiological changes. Associated with these results we have found a gradual increase in the nitrogen content of the yeast cells.

13. Dr. Guilford B. Reed.—*The Influence of Salt and Hydrogen Ion Concentration upon the Growth and Structure of Bacteria.*

The growth of several species of bacteria in dilute peptone or pure protein solutions is increased with the addition of NaCl to a maximum which varies with the species. The addition of the salt widens the pH tolerance. Further increase in the concentration of NaCl decreases the growth and decreases the pH tolerance.

In very dilute NaCl and at optimum pH for growth the organisms are of a characteristic form, at pH higher or lower than optimum the organisms vary in structure, usually they are larger, and at the extremes of pH for growth consist of still wider structural variants from the characteristic form. In the optimum NaCl concentration for growth the organisms are more nearly typical in form with less variation in structure at the extremes of pH. In concentrations of NaCl above optimum for growth the organisms are all atypical in form, with conspicuous modifications in structure at the extremes of pH.

14. Prof. G. N. Stewart.—*Colour Phenomena caused by Intermittent Stimulation with White Light.* (Demonstration.)

Attention having been called to studies on subjective colour phenomena caused by intermittent stimulation with white light published by the author in 1888 (*Proc. Roy. Soc. Edin.*, 1888, 445-464), many unpublished data obtained then or

subsequently are now presented. Simple methods are demonstrated by which the colours can be produced in a striking manner, particularly in black-and-white pictures.

Studies have also been made on the colour changes produced in coloured after-images by intermitting the light from the ground on which they are viewed. The changes are essentially similar to those seen when external illuminated objects are viewed with a rate of intermission below that required for fusion, and occur in the same general sequence, although the phenomena are more complicated owing to the colour effects associated with the decay of the after-images themselves and other factors.

15. Dr. R. A. Waud.—*Demonstration of an Electro-polygraph.*

16. Dr. F. W. Edridge-Green.—*Temporary Colour-Blindness.*

Though congenital colour-blindness has chiefly occupied the attention of those who have paid attention to the subject, it is well known that colour-blindness may be acquired through disease or injury. These cases have been regarded as permanent. It is, however, not known that colour-blindness similar in character to a very bad dichromic may occur as a purely temporary condition.

The colour sense, even with normal-sighted persons, varies according to the condition of the health. When a series of colour equations have been made by three normal-sighted persons it will be found that on certain days one of the three will put more or less green in the equation than on the previous occasion, whilst the other two observers will make the same equation as before. This condition, whilst a disturbing factor, usually varies within the limits of normal colour-vision. The nerve cells whose function it is to perceive colour seem to be much more liable to affection by disease, especially by toxic influences, than those of the visual centre. Acquired colour-blindness seems to be closely related in its general characters to the congenital form. A man suffering from general paralysis of the insane may pass through all the degrees of congenital colour-blindness. A woman became totally colour-blind after ear disease; she was examined when she was regaining a certain amount of colour perception and could distinguish between red and violet, the rest of the spectrum appearing grey. A signalman became totally colour-blind after tetanus, his visual acuity being partly 6/6; he had previously passed the wool test several times.

The following is an illustrative case. The examinee was a man who had just recovered from influenza, but he appeared perfectly well and made no complaint of any kind. His form vision was 5/5 partly, both eyes being used. Examined with the lantern, he called green both white and red; red he called white, and white red.

Examined with the spectrum, he called the region from λ 650 $\mu\mu$-λ 571 $\mu\mu$ (red, orange, yellow, and yellow-green) red; the region from λ 571 $\mu\mu$ to λ 538 $\mu\mu$ (green) white; the region from λ 538 $\mu\mu$ to λ 442 $\mu\mu$ (green, blue, and violet) blue; and purple from λ 442 $\mu\mu$ to the end. The apex of his luminosity curve was at the normal point λ 585 $\mu\mu$. He made the following equations: 45 red λ 665 $\mu\mu$ mixed with 2 of green λ 520 $\mu\mu$ matched 15 white. The normal equation is 45 red with 13 green equals 16 white, so that he was matching a bright red with white. He made an equation of 10 λ 633 $\mu\mu$ red with 6 λ 540 $\mu\mu$ green equals 22 white. He also agreed with the normal equation, which is 10 red and 10 green equals 20 white, but required the comparison white light increased in luminosity. Examined again five months afterwards his colour-vision was normal in every respect.

17. Prof. V. E. Henderson.—*The Movements of the Small Intestine.*

A study of intestinal peristalsis recently made led the author to consider that the nerve net played an important part in its production, and that it did not depend for its propagation on muscle alone. A further study has shown that the sensitivity of the gut to internal pressure changes at different levels differs, but that the upper parts are not more sensitive, but less so than the lower. Further evidence of the activity of the net is offered.

18. Dr. Robert Chambers.—*Microdissection Studies on Viscosity Differences in the Egg during Cleavage.*

The cleavage of the egg is accompanied by a definite series of localised changes in the viscosity not only of the cytoplasm but also of the nucleus.

The viscosity changes in the cytoplasm centre mainly about the two poles of the mitotic spindle.

In the surface of the dividing egg the viscosity is very low, and definitely directed currents appear at the time of actual cleavage process. Localised surface currents can be made to appear by moving the spindle with a micro-needle to the surface of the egg.

Agents which inhibit cell division do so by producing generalised viscosity changes, and thereby eliminating the localised differences upon which the division of the cell depends. In this way cell division can be temporarily stopped by either a solidifying or liquefying agent.

19. Dr. G. H. A. Clowes.—*Protoplasmic Structure and Function, particularly as regards Physical and Chemical Conditions Governing Cell Division.*

20. Dr. Carl Voegtlin, Dr. J. M. Johnson, and Miss Helen A. Dyer.—*The Quantitative Estimation of the Reducing Power of Normal and Cancer Tissue.*

A method is described for the estimation of the reducing power of tissues and biological fluid by means of various oxidation reduction indicators. The fundamental principles underlying the use of these indicators in biological work have been investigated, and a comparison was made of the values yielded by the purely physical system using the electrode and the results obtained by means of living tissue. A remarkable parallelism in the results of the two methods was found to exist.

Preliminary observations have also thrown light upon the chemical character of the substance occurring in protoplasm which is responsible for the reduction of the indicators.

Monday, August 11.

21. Joint Discussion with Section B on *Vitamins and the Relation of Light to their Action.*

(*a*) Prof. J. C. Drummond.—*Modern Tendencies of Vitamin Research.*

(*b*) Prof. H. C. Sherman.—*The Quantitative Distribution and Nutritional Significance of Fat-Soluble Vitamin.*

(*c*) Prof. Walter H. Eddy.—*The Isolation of a Bios from Autolysed Yeast.*

(*d*) Prof. E. Mellanby.—*The Interaction of the Anti-Rachitic Vitamin and other Factors of the Diet.*

(*e*) Prof. W. Lash Miller.—*The Fractionation of Bios.*

Mr. G. H. W. Lucas' fractionation of bios; last winter's work on the preparation and purification of Bios I and Bios II. Miss E. V. Eastcott's study of the formation of the bioses in filtered vegetable infusions.

(*f*) Prof. W. Steenbock.—*Radiant Energy as the Anti-Rachitic Factor.*

(*g*) Prof. H. M. Evans.—*Existence and Characteristics of a New Vitamin necessary for Mammalian Reproduction.*

22. Prof. A. B. Macallum, F.R.S.—*Criticism of the new Micro-Chemical Methods for the Estimation of the Inorganic Constituents of Animal Fluids.*

23. Prof. W. R. Bloor.—*The Unsaturated Fatty Acids in Metabolism.*

The stored fat in warm-blooded animals consists largely of glycerides of the saturated fatty acids and of unsaturated acids of a low degree of unsaturation, mainly oleic acid. The fatty acids found combined in the lipoids of the active tissues of these animals, as for example in the liver, kidney, brain, heart, and, to a less marked extent, the muscles, contain a much higher percentage of unsaturated acids, and these are of a considerably greater degree of unsaturation than those of the fat stores. According to Leathes' hypothesis of fatty-acid catabolism, the fatty acids of the stores are prepared for use in the tissues by a process of desaturation which takes place mainly in the liver. The desaturated acids are then conveyed by the blood to the tissues. The fatty acids are never free but always in some sort of combination, and in the solution of the problem of their catabolism it is important to know not only the nature of these unsaturated acids but also the combinations in which they occur and their distribution among these compounds. The present paper consists of a discussion of these topics, having special reference to the blood plasma under normal and experimental conditions.

24. Prof. H. Wasteneys and Mr. H. Borsook.—*The Enzymatic Synthesis and Hydrolysis of Proteins.*

The authors have succeeded in effecting the enzymatic synthesis of protein in peptic digests of albumin. The maximum synthesis so far obtained has been 39 per cent. Proof that the material synthesised is of the order of complexity of native protein is furnished by incontrovertible evidence satisfying all criteria for protein.

The optimum hydrogen ion concentration for peptic synthesis is at pH 4.0. For tryptic action, on the same digest, it is at pH 5.7. The amount synthesised is inversely proportional to the dilution. At a concentration of 8 per cent. of products, synthesis fails to occur with concentrations of enzyme varying from 0.04 per cent. to 4 per cent. In a 6-per-cent. solution in which hydrolysis at 38° C. had gone to completion, synthesis was effected by raising the temperature to 65° C., without the addition of further enzyme, or the concentration of the solution. These effects of dilution, and of temperature, and further experimental evidence of reversibility, are shown to be predictable from thermodynamical considerations. Addition of synthesised protein, or egg albumin in varying amounts, to a solution in which synthesis is in progress, inhibits in simple direct proportionality the amount of protein formed. The enzyme responsible for synthesis was found to be inseparable in every respect from the enzyme effecting hydrolysis.

25. Dr. D. D. Van Slyke.—*The Distribution of Electrolytes in the Blood.*

On the basis of the assumption that the osmotic pressure in the cells and plasma is proportional to the ratio $\frac{\text{molecules}+\text{ions of solute}}{\text{molecules of water}}$, and that Donnan's law governing the distribution of diffusible and non-diffusible ions in solutions separated by a membrane is valid, mathematical expressions have been derived which relate the distribution of electrolytes and water between cells and serum, and between serum and edema fluid, to the alkali-binding power of the proteins as a primary factor. From determinations of the alkali bound by the cell and serum proteins at varying pH, and the influence of oxygenation and reduction on the hæmoglobin in this respect, the distribution of the diffusible monovalent anions HCO_3' and Cl' has been calculated, and the effects thereon of changes in CO_2 and O_2 tension. The distribution between serum and edema fluid has

been similarly calculated, and the effect of hæmolysis on the buffer curve of the blood. The calculated values have been compared with those experimentally found.

26. Prof. P. A. Shaffer.—*The Ketolytic (antiketogenic) Action of Sugars* in vitro.

On the hypothesis that antiketogenesis in the animal body is due to a chemical reaction between acetoacetic acid and an intermediate product of the oxidation of glucose, similar to the 'ketolytic' action of sugars *in vitro*, the latter reaction has been studied in some detail. Although efforts to isolate the intermediate condensation product in the reaction with sugars have failed, analogous products are easily obtained. The rate and final products of the ketolytic reaction with different sugars give fairly conclusive evidence as to the type of reaction concerned. It appears to be a Knovenagel condensation of acetoacetate with osones, the first oxidation products of the sugars, the condensation product at once losing CO_2 and being oxidised to formic, acetic, and glycolic acids. In so far as the *in vitro* reactions can be assumed to represent reactions in the animal body, they indicate that osones are probably formed in the physiological oxidation of glucose. And if this be the case, glucose cannot be oxidised via lactic acid.

27. Dr. E. Gordon Young.—*The Decomposition of Glucose by Bacterial Enzymes.*

A stock laboratory strain of *B. coli communis* fermented pure glucose in a suitable salt medium after gross sowing, yielding the variety and proportion of products obtained by other workers with different strains. Single cell isolations from this strain were made by the Chambers micro-manipulator and fermentations carried out under identical physico-chemical conditions. Several types of fermentations resulted differing in the quantitative aspect of the products formed, lactic acid and carbon dioxide or acetic and succinic acids predominating. The same type was maintained in subsequent fermentations after single- or multiple-cell sowings from the isolated strains.

This is taken to suggest that the ordinary bacteriological strains of *B. coli communis* contain cells possessing different types of metabolism considered chemically. It further reinforces the idea that glucose may be broken down along several paths.

Tuesday, August 12.

28. Prof. J. J. R. Macleod, F.R.S., Miss K. O'Brien, and Mr. J. Markowitz.—*Some Further Experiments on the Physiological Action of Insulin.*

The reducing substances present in alcoholic extracts of muscle and liver prepared at low temperatures have been studied in normal animals under the influence of insulin, but no evidence has been obtained that would indicate the nature of the chemical change that is responsible for the disappearance of blood sugar in the latter condition. The inorganic phosphate and the acidogen phosphates of muscle following insulin have been found to undergo certain changes which may, however, be related to the increased muscular activity. The excretion of phosphorus in the urine can be almost, if not entirely, suppressed in normal animals by insulin, and this is accompanied by a rise in nitrogen excretion (Allan and Sokhey).

The diastase content of the blood which is much lowered in depancreatised dogs is raised by administration of insulin. There are also interesting changes in the esterases. Insulin retards the rate of glycogenolysis following piqure and ether as well as that following epinephrine.

29. Mr. C. H. Best and Mr. R. G. Smith.—*The Effects of large doses of Insulin on Dogs.*

The fact that small doses of insulin may exert as rapid, and in many cases as pronounced, effects upon rabbits as much larger doses has been commented

on by several groups of investigators. We are interested in this investigation, with the effects produced on the normal and diabetic dog by the administration of varying amounts of insulin. The results indicate that a small dose (10 units) may exert as rapid and nearly as prolonged an effect upon the blood sugar of a normal dog as a much larger dose (100 units). A study of the symptoms produced in dogs by large doses of insulin has been made.

30. Dr. J. H. Burn.—*The Factors controlling the normal output of Sugar from the Liver.*

31. Dr. E. C. Albritton.—*Blood Sugar during continuous Intravenous Injection of Glucose.*

Continuous intravenous injection of glucose at the rate of 0.7 gram per kilo. per hour into a superficial vein in dogs resulted in persistent hyperglycemia during the injection, averaging 50 mgm. per 100 cc. above the initial level. Injection was made for two and a-half hours in twenty-two experiments. In only one of these did the elevated sugar-level fall to its initial value during the injection period. Injection for periods of five hours in dogs under amytal anæsthesia gave a similarly persistent hyperglycemia. In ten experiments in which very frequent blood samples were taken irregular oscillations were found to occur in the blood-sugar level. These oscillations averaged 15 mgm. per 100 cc. in amplitude and fifteen minutes in period. They were not due to irregularities in the rate of injection, nor to experimental error. Similar oscillations did not occur in the hæmoglobin percentage.

In thirteen dogs under amytal anæsthesia the sugar was injected into the arterial circulation of the pancreas in order to subject the gland to the influence of a stronger concentration of sugar. In eight of the resulting curves the hyperglycemia was persistent as before, and in six even higher than usual In five it was either markedly lower than usual or only transient, gradually falling to or below the initial sugar-level. Such low blood-sugar curves are interpreted as evidence of more active loss of sugar from the blood than the curves in which the hyperglycemia persists.

The high proportion of these low curves in the injections into the pancreas, five out of thirteen, as compared with one out of twenty-two in the injections into a superficial vein, indicates that subjection of the pancreas to a higher blood-sugar may cause a more active loss of sugar from the blood. It is concluded (1) that unexplained fluctuations may repeatedly occur in the course of the blood-sugar curve during glucose injection at the rate used; (2) evidence is adduced which favours the hypothesis that the blood-sugar is the stimulus to insulin discharge.

32. Dr. P. J. Moloney and Dr. D. M. Findlay.—*Further contributions to the Chemistry of Insulin.*

The paper has to do with properties and the purification of insulin. It reviews earlier work of the authors on adsorption as a method of purification; details a plan for the application of this method to the purification of insulin, and gives results obtained. Work with some new precipitating agents for insulin is reported, and the possible significance of some of the reactions involved is pointed out.

33. Prof. E. P. Cathcart, C.B.E., F.R.S.—*The Significance of the Respiratory Quotient.*

The question of the meaning of the R.Q. is one of importance at the present moment, as the estimation of the energy expenditure by the indirect method, which is now so much in vogue, is based on the relation between the oxygen utilised and the carbon dioxide given off.

Emphasis is laid on the fact that the respiratory quotient is not an entity; it is the resultant of the interaction of many forms of activity, in part physical, in part chemical.

It is common experience that R.Qs are obtained which lie above and below the nominal values for the perfect combustion of carbohydrate and fat. These

'abnormal' R.Qs do not necessarily arise from errors in technique. When such 'abnormal' values are obtained under conditions when it is presumed 'pumping out' and 'debt' are excluded, how are they to be used for the determination of the energy expenditure in terms of calories?

34. Prof. A. T. Cameron.—*The Effect of Absorbable Intestinal Toxins on Metabolism.*

Meat was digested with pepsin-HCl, the digest neutralised, and minced intestinal mucosa and pancreas added. The digest was subsequently infected with normal fæces, and bacterial action allowed to proceed for ten to fourteen days. The mixture was strained through linen and added to 5 volumes of alcohol. The filtrate, freed from alcohol, gave no biuret reaction. Injected daily, intramuscularly, into dogs, it produced distinct chloride retention, and a rhythmic effect on total-N and urea excretion (a fall, then a greater rise), which could be repeated by increasing the injection dose. The results may perhaps be compared with the chloride retention caused by artificial intestinal obstruction (Haden and Orr, 1923), and that which occurs after deep X-ray therapy, especially of the epigastric region (observed by Cori and Pucher, 1923, and confirmed, in unpublished work, by the author and J. C. McMillan).

35. Prof. G. H. Parker.—*The Carbon Dioxide excreted by Nerve.*

The amounts of carbon dioxide excreted by the lateral-line nerve of the dog-fish, the sciatic nerve of the frog, and the ventral chain of the lobster were determined by an indicator method. The quiescent frog nerve produced on the average nine thousandths of a milligram of carbon dioxide per gram of nerve per minute. In active nerve this was increased by about 12 per cent. By subtracting from the total amount of carbon dioxide produced by the lateral-line nerve the amount due to the connective tissue of this nerve, and by dividing the remainder by the number of nerve fibres in this nerve, it was shown that 1 centimetre of quiescent cold-blooded nerve fibre excreted on the average twenty-nine billionths of a milligram of carbon dioxide per minute. Weight for weight the resting frog nerve produces about the same amount of carbon dioxide as the resting human body does.

36. Prof. Frank Allen and Dr. A. Hollenberg.—*The Tactile Sensory Reflex.*

By interrupting a jet of air with a rotating sectored disc, the state of the tactile receptors on the volar aspect of the right index finger was measured when in their normal condition. It was found that the measurements conformed to the law $D = -K \log. P + C$ where D is the duration of the impression at the critical frequency of percussion of the interrupted air jet, and P the pressure.

The experiments were repeated when the finger was fatigued by pressure. When the adjacent digits were bandaged it was found that the receptivity of the original tactile receptors was enhanced, thus showing the existence of a tactile sensory reflex. Post-fatigue and light-touch enhancement were also found to exist and were measured. The laws governing the sense of touch, and the influence of one finger on another, are similar to the effects obtained in optics. The results are applied to various physiological phenomena.

37. Prof. Frederick R. Miller and Dr. H. M. Simpson.—*Studies in Visceral Reflexes.*

We have found that in the viscero-motor reflexes of Sherrington and MacKenzie, besides the abdominal muscles, the muscles of the hind limbs are involved as effectors. The hind-limb reactions consist in powerful, tonic, muscular contractions, associated with movements of escape.

Viscero-motor reflexes were elicited by mechanical or chemical stimulation of various viscera, as well as by faradisation on visceral, sympathetic nerves. We suggest that the drawing-up of the legs in abdominal, visceral disease in man is dependent on reflex contractions of the psoas and iliacus muscles, since we observed the iliopsoas muscle to contract in the viscero-motor reflex.

The protective nature of the viscero-motor reflexes renders logical the assumption of their association with pain in the intact organism.

38. Prof. Lafayette B. Mendel, Prof. Thomas B. Osborne, Prof. Edwards A. Park, and Dr. M. C. Winternitz.—*Variations in the Kidney related to Dietary Factors.*

There is a widespread popular belief that a high-protein diet in man is a renal irritant. Inasmuch as rats will grow on rations extremely rich in protein, provided all other dietary essentials are supplied, it has been possible to study the development of their organs under such conditions. The kidneys become strikingly hypertrophied, but histologic examination has failed to disclose changes of an inflammatory or degenerative nature. The renal hypertrophy occurred without hypertrophy of the heart. When renal function is greatly augmented by certain factors other than the necessity of eliminating nitrogenous waste, hypertrophy does not develop in the same way. The chemical features that may be related to the functional hypertrophy of the kidney are being investigated.

39. Dr. Ivy Mackenzie.—*Orthopedic Deformity and the Dissolution of Central Nervous Integration.*

Gun-shot wounds of the limbs were followed frequently by orthopedic deformities which could not be explained on the current conceptions of the functions of peripheral nerves. In the upper limb, wounds in the musculo-spiral segment were rarely followed by serious sequelæ; wounds in the ulnar segment had frequently serious sequelæ. Operations on the ulnar nerve were not so successful as those on the musculo-spiral. A wound in the musculo-spiral segment might give rise to a deformity in the ulnar segment; a wound in the ulnar segment never gave rise to a deformity in the musculo-spiral segment. These differences are to be attributed to a difference in neural complexity between the lower and the upper segments of the cervical enlargement. The lowest segment (first thoracic) contains central neurones of the sympathetic system; the upper segments do not. The lowest segment contains also the motor neurones and terminal sensory neurones of the ulnar nerve which is concerned with the finer movements of the hand. Hence the tendency to orthopedic deformity in the ulnar segment of the limb from functional dissolution of its central nervous integration in the cord.

SECTION J.—PSYCHOLOGY.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 469.)

Thursday, August 7.

1. Prof. T. H. Pear.—*Privileges and Limitations of Visual Imagery.*

The desirability of studying in detail the extent to which the memory, thinking, and judgment of an individual may be affected by the type of imagery which predominates in his mind. The concept of imagery as a cage, limiting one's appreciation of the world, illustrated by the one-sided visualiser's lack of kinæsthetic or 'muscular' imagery. Some persons seem more conscious than others of their confinement in imagery.

The belief that visual imagery characterises minds of lowly organisation. Is this always true? The possibility that there is a technique of arriving at truth along visual routes. May different classes of imagery, like differently coloured searchlights, illuminate the facts of existence in their own inimitable ways?

The intimacy, privacy, and personal appropriateness of visual imagery. Its influence upon judgment. Can there be a visual logic? *Propria* in the world of visual memory.

Is the verbaliser caged? The personal and impersonal use of words.

2. Prof. J. W. Bridges.—*A Reconciliation of Current Theories of Emotion.*

For the introspectionist emotion is a stirred-up state of mind analysable into kinæsthetic and organic sensations and feelings, which may or may not be further reducible to organic sensations. This is probably a correct account of emotion from the subjective and analytical standpoint.

For the Behaviorist emotion is 'hereditary pattern-reaction involving profound changes of the bodily mechanism as a whole, but particularly of the visceral and glandular systems.' Emotion is thus analogous to instinct, but the latter is chiefly a skeletal, and hence more overt response. This may be regarded as a true account from the objective standpoint.

According to the James-Lange theory the emotion is the consciousness of the response. James laid special emphasis on the skeletal response, Lange on the vascular. This view may be modified in such a way as to make the emotion the *subjective accompaniment* of the response, and the response that described by the behaviorist.

According to McDougall, emotion is the subjective aspect of an instinct. If we regard the instinctive response as chiefly skeletal and the emotional response as chiefly visceral, then the two will frequently occur together, since the same situation will often lead to both types of response. There is not, however, the *necessary connection* between the instinctive response and the emotion demanded by McDougall's view. Skeletal and visceral responses may occur together, but skeletal may also occur without visceral or visceral without skeletal. Thus, for example, pugnacity and anger may occur together, but pugnacity may occur without anger or anger without pugnacity.

Drever distinguishes between instinct-interest, which is the invariable accompaniment of instinct-activity, and emotion, which occurs in consequence of some check to instinctive activity. Kantor expresses a similar view of emotion. As has been stated above, emotion may and often does accompany instinct-activity. If, however, the instinct-activity is checked, the energy, which would have been thus released, may be drained into the vegetative nervous system. The emotional responses would then be increased, and the accompanying emotional consciousness intensified. The emotion is not due to the check, but may be intensified by it.

All of the above theories are, therefore, part-truths or contain elements of truth, and most of them err in so far as a part-truth is mistaken for the whole truth. Emotion is a psychophysiological response of a particular kind. It has its subjective as well as its objective aspect. It is similar to, but not identical with, nor a necessary concomitant of instinct; and it *may* be intensified when the instinctive response is checked.

3. Mr. J. C. Flügel.—*Feeling and Emotion in Daily Life.*

4. Prof. W. Tait.—*Classification of Instincts.*

Many classifications of instincts have been made from the physiological point of view, such as Thorndike's, which apparently does not differentiate instinct from reflex action. Others again, such as Warren's, are a combination of logical, psychological, and social considerations. McDougall's list is the only one which is psychological, and his appears to be based upon introspection.

The present discussion owes its origin principally to McDougall and Rivers—the former's 'Social Psychology' and 'Outlines of Psychology,' and the latter's 'Instinct and the Unconscious.' Psychoanalysis, too, has been of service.

Briefly, it is held that there are two primary or principal instincts which make for preservation of the race and the individual. The former may be termed the sex instinct; the latter the self instinct. They are mutually complimentary, although either one may be very indistinct in some individuals. These are termed primary instincts.

Other instincts with well-marked emotional accompaniments may be considered as subsidiary to these two, and the expressions of the latter as dependent upon the particular structure which the organism may possess. For example, the food instinct may be part of the self instinct; nest-building, part of the

sex instinct; hunting, as belonging to both, &c. On this basis, too, pugnacity need no longer occupy a special *rôle* as in McDougall.

Curiosity, fear, &c., are therefore termed secondary instincts, and others, such as acquisition, are derived instincts. No instinct should be considered either as primary or secondary unless it has a well-marked emotional attitude.

5. Dr. J. Drever.—*Psychological Theories of Laughter.*

A biological account of the function of laughter is not a psychological theory. For a psychological theory we require to know the psychological nature and relations of laughter.

Primarily laughter would appear to be the expression of all joy emotions when they reach a certain degree of intensity.

Joy emotions may be evoked, and therefore laughter, by a sudden relaxation of 'tension.'

Emotion of all kinds, and therefore laughter, may be evoked either directly, or sympathetically, or empathetically.

6. Prof. A. P. Weiss.—*One Set of Postulates for Behavioristic Psychology.*

7. Prof. F. Aveling.—*The 'Self' in Cognition: Intuition, Concept and Sensory Percept.*

Connection of psychology with philosophy and the physical sciences. The epistemic problem. The self as immediate object of awareness. The controversy between the 'self'-psychologists and their critics. Miss Calkins's investigation of experimental evidence for immediate awareness of the self; brief exposition and criticism. Further introspective evidence from researches on conceptual and volitional processes. Intuition of the self distinguished from concept of the self, and from sensory percept. Citations from protocols. Objections to the thesis. Descriptions of the self. Consequences in psychological method.

8. Prof. G. S. Brett.—*The Value of Mnemic Psychology for the Interpretation of Dreams and other Phenomena.*

The object of this paper is to explain a number of observations on dreams and such states as reverie, stupor, astonishment. The terms used by Semon will be employed to explain in what sense the images which form the mental content can be called memories. The subject is divided according as the sense elements or the ideas are involved. In reference to the former it is held that the stimulus is the origin of a reaction which is conditioned by specific organic conditions defined as levels of vigilance. The ideational content is defined as a plan of action which is part of the total response, but becomes disintegrated or frustrated. The effort to reinstate total awareness and to act according to a plan is held to be the nucleus about which the other elements are grouped. From this can be derived a principle of analysis for the study of character. The phenomena here discussed are not to be classed as abnormal, though they may be distinct from the experiences of the waking state.

Friday, August 8.

9. Joint Discussion with Section I on *Physiological and Psychological Factors of Muscular Efficiency in Industry.*

(*a*) Prof. E. P. Cathcart, C.B.E., F.R.S.—*The Calculation of the Mechanical Efficiency of the Performance of Muscle Work.*

(*b*) Prof. E. A. Bott.—*Co-ordinate Volitional Action of Antagonistic Muscular Groups.*

Problem.—The type of movement produced by antagonistic muscle groups under experimental conscious control.

Conditions of Experiment.—Movement of right *wrist* arranged as previously reported in *Brit. Journ. of Psych.*, July 1923.

Subject endeavours to produce reciprocal movements at maximum rate and with greatest accuracy of amplitude. Combination of visual and kinæsthetic control.

For non-reciprocating strokes limb is flexed at maximum speed from a resting position on an auditory signal.

Known loads given gravitionally, also by friction.

Registration of movement by kymograph with co-ordinate analysis of resulting graphs.

Findings.—(A) In reciprocating strokes.

(1) After allowing practice, successive strokes in a series still vary greatly in length. This variation in length of stroke is not rhythmical, is not appreciated by the subject introspectively, and is not under voluntary control.

(2) The duration of successive strokes is fairly constant, although long strokes actually occupy a slightly longer time than short ones, the correlation between duration and amplitude being never greater than plus .6, though being regularly of about this magnitude. Thus while rhythm is prominent in the incidence of strokes, it is not absolute.

(3) A striking regularity is found in the fact that the progression rate of a stroke (the average time per unit of amplitude) is in inverse proportion to the total amplitude, this relationship having a correlation as high as plus .96. The length of a reciprocating stroke is, therefore, an *effect* only, long strokes being long because the limb is moving rapidly, while short strokes are those of slow rate, each sort being of approximately the same total duration as indicated in (2).

(4) Finally, it is found that the excess or defect of rate is never localised in any particular portion of a stroke, but characterises the whole of it in such a way that the progression curve (proportion of stroke amplitude to proportion of stroke duration) is identical in form for long and short strokes in a given series of reciprocal strokes.

The important point, therefore, about reciprocating movement by antagonistic muscles acting under maximum effort as here is the fact that each stroke at its very initiation has about it those characteristics of acceleration which completely determine what the whole stroke is to be. Its character as long or short is already pre-determined when once the stroke has begun.

Questions.—(1) What determines the progression rate of a stroke; what part is played by the preceding stroke (which itself may have had a very different rate)?

(2) Do the antagonistic muscle groups alternate in action at the same moment, or with an interim of no action, or do they overlap in action?

(3) Do the antagonistic groups cease and commence action abruptly or gradually under one or another of these conditions?

(4) Assuming that there is some point (instant) in reciprocation which would best designate the 'change' in muscle action (*e.g.*, from flexors to extensors), where is this point in relation to the stroke cycle? Does it coincide with the point of change in direction of limb movement? This may be answered in the negative as follows :—

Findings.—(B) In non-reciprocating strokes.

If, in a reciprocating stroke, the limb movement (*e.g.*, flexion) commences immediately the flexors begin to contract, it should be possible to duplicate this movement by flexing the limb at maximum speed from a free resting position. When this is done under similar conditions of control the initial rate of movement is very considerably less than that obtainable in reciprocation. No amount of readiness or effort on a subject's part can produce a curve from a 'standing start' as steep as that he regularly achieves when reciprocating. The non-reciprocating stroke, of course, eventually acquires the greater speed, and a place on its course can usually be found which approximates the initial portion of his reciprocating curve. The inference is (1) that in reciprocation the movement of the limb in a particular direction commences considerably later than the corresponding muscle action, and thus has as it were a 'flying start'; (2) by

curve fitting a rough indication may be had of how far back in the preceding stroke the change in muscle action took place.

Another peculiarity of non-reciprocating strokes is that the initial rate of motion which can be voluntarily given a limb starting from rest is greater the *greater* the load up to a certain limit, after which the initial possible rate decreases to the point of immobility. This feature seems to vary in some degree with the conscious factor (*a*) whether the subject has or has not knowledge of the load to which he is to be subjected; (*b*) the degree of muscle tension he maintains when awaiting the signal to stroke.

(*c*) Dr. C. S. Myers, C.B.E., F.R.S.—*Conceptions of Fatigue.*

Fatigue may arise from the exhaustion of the material stored up by living substance for the manifestation of its specific activity (contraction, heat sensation, &c.) or from the accumulation of the waste products of such activity. This kind of fatigue occurs usually after powerful *spasmodic acts*; and at present, at least, it is to be distinguished from the fatigue affecting the *continuous set* of control or direction, which results in posture and in orderliness of acts. Two kinds of set may be usefully recognised: 'Extrinsic set' involves inhibition of unfavourable or incompatible acts or sets; it preserves a favourable 'attitude' (mental or motor). 'Intrinsic set' involves poise between antagonistic acts; in muscle it is manifest as protracted tone or posture, and visual and thermal sensibility as adaptation to colour (or brightness) and temperature. Adaptation is thus a state of posture, not a state of fatigue. Throughout mental and muscular activity, direction and the elaboration of material for acts concur, posture and attitude being the matrix in which acts occur, the former engaged rather in elevating, the latter in degrading energy. In everyday life, the former kind of fatigue is of far greater importance than the latter. On it depend the acquisition, preservation, and manifestation of skill, attitudes of attention, &c.; but of its nature we are ignorant.

(*d*) Prof. F. S. Lee.—*Physiological Aspects of Efficiency in Industry.*

10. Presidential Address by Prof. W. McDougall, F.R.S., on *Purposive Striving as a Fundamental Category of Psychology.* (Page 226.)

11. Dr. Morton Prince.—*The Problem of Personality.*

12. Wing-Commander E. C. Clements.—*Binocular Vision and Correct Ocular Muscle Balance: its importance in everyday life.*

From the experience of clinical practice and special experiments the author has formed the opinion that binocular vision with correct ocular muscle balance is necessary (1) for the correct mental interpretation of impulses received, and (2) for efficient muscular co-ordinative response thereto. Lack of the above requirements has been found in many cases to account for (1) inability to land aeroplanes; (2) lack of manual dexterity or clumsiness at certain occupations; (3) lack of skill at games requiring 'eye'; (4) loss of efficiency of performance in acts such as above due to fatigue, illness, or other causes. In many cases by special visual training exercises the defects can be removed and correct performance of the various acts ensured.

13. Prof. E. A. Bott and Mr. S. F. N. Chant.—*A New Method of Stereoscopy, with Applications to Motion Pictures.*

The discoveries of Wheatstone and Brewster in stereoscopy attracted worldwide attention in the middle of the nineteenth century. This interest as quickly died out because no result of scientific importance nor any useful application was at that time found for this remarkable visual phenomenon, and in consequence the stereoscope became little more than a household toy. Later in the century interest was revived in some circles through the use of certain characteristics of stereoscopic fusion in the detecting of forgeries and counterfeits, the matching of pattern materials, the surveying of inaccessible regions, astro-

nomical, meteorological, terrestrial, in range-finding, &c. And more recently persistent attempts have been made to find a possible and practicable means of exhibiting motion pictures in full relief to public audiences.

In this communication the basic principles of successful stereoscopy will be discussed and the main methods that have been tried in connection with motion pictures will be reviewed. In the new method to be presented a return is made in part to the original principles which Brewster used for the viewing of small pictures in three dimensions, but with modifications necessitated by the use of large pictures that may be exhibited in public. Types of stereoscopes adapted for this purpose will be shown, and during the meetings a demonstration will be arranged for those who may be more particularly interested.

The stereoscopy of projected pictures raises a number of new and significant problems in visual science, a few of which will be touched upon in the concluding part of the paper.

Saturday, August 9.

Informal Conference of Experimentalists on Laboratory and Applied Researches.

Chairman: Dr. C. S. Myers, C.B.E., F.R.S.

Monday, August 11.

14. Joint Discussion with Section L (*q.v.*) on *Tests for Scholarships and Promotions.* (Page 456.)

15. Joint Discussion with Section H on *Racial Mental Differences.* Prof. W. McDougall, F.R.S., Dr. C. S. Myers, C.B.E., F.R.S.

Prof. W. McDougall, F.R.S.—

It is a matter for rejoicing that anthropologists are now becoming interested in the question of mental peculiarities of races and the differences of innate mental constitution between races. Unfortunately there is no approximation to agreement on these questions among psychologists. The majority of them, perhaps, under the influence of the dogma that man is nothing more than a bundle of mechanical reflexes, adheres to the popular view (determined by humanitarian sentiment and religious beliefs) that there are no such differences. This popular superficial view is also in part a reaction against an older popular view to the effect that the difference of knowledge and culture between civilised man and a savage expresses or corresponds to a similar difference of innate mental endowment. Those who examine this question, impartially and uninfluenced by any of these popular beliefs and dogmas, agree that there are differences of innate mental constitution between races; but they differ widely as to the nature of these differences and as to their importance in determining the differences of nature and level of the cultures attained by the several divisions of the human race.

The exacter methods of observation furnished by experimental psychology have attained two conclusions which may be regarded as well founded.

First, the Cambridge Anthropological Expeditions of 1899 showed that two of the coloured races, Oceanic negro and Malayo-polynesian, differ from the white race in respect of sensory capacities hardly at all; the differences found were so small as to furnish no ground or explanation for differences of cultural achievement. Later work has but confirmed this conclusion, and it may be regarded as established that most, and probably all, branches of the human race enjoy sensory capacities which natively are extremely similar in range and culture.

Secondly, the methods of intelligence testing seem to have revealed certain racial differences in respect of 'general intelligence' or innate capacity to develop 'general intelligence.' Whether 'general intelligence' is a true unit character in the Mendelian sense or in the psychological functional sense

remains still an open question. But that uncertainty does not invalidate the conclusion drawn from the mental tests. It seems to have been shown, e.g. that the negro race has statistically or on the average a lower endowment of 'general intelligence' than the white race. It is still possible for those who on humanitarian grounds dislike this conclusion to dispute this finding. But I have little doubt that further research will confirm it. For it is in harmony with much evidence of a less exact and direct kind, evidence provided by a review of the history of the negro race, whether in its original habitat or in those regions where it has long been in intimate contact with highly civilised people. If we attempt to go further and raise the question of more specific differences of racial mental constitution we find wide differences of opinion, and are on ground where the evidences are very obscure, where the interpretation of them requires a long training in psychology, and where various psychological theories cannot fail to affect very greatly that interpretation. Taking into account only the views of those who by much psychological study have earned competence to express an opinion, I think we may distinguish two principal views, which we may call the advanced and the conservative respectively. The former is best represented by Dr. C. G. Jung, and is shared by other members of the psycho-analytic schools of Freud and Jung. It holds that study of symbolism, especially that of myths and dreams, reveals certain forms of symbolic thinking as common to men of all races, and special varieties of these forms as peculiar to certain races, common to all or most members of such races. These symbolic modes of thinking, which Jung calls archetypes, constitute, in his view, an innate basis of the intellectual life of each race, a basis common to the race which Jung speaks of as the racial or collective unconscious. He attributes to it a profound influence upon the forms of culture and the intellectual life of each race, including especially its religion and philosophy. The symbolism of the Freudian system has similar implications, though that school has not elaborated this part of its doctrines. This view, if true, is of profound importance. And we have no knowledge that makes it untenable. Perhaps the most serious objection to it is that it seems to imply the reality of Lamarckian transmission. But in the present state of biological knowledge that cannot be regarded as an insuperable bar to the tentative acceptance of this view. Its truth remains a question to be settled only by the further collection and weighing of the empirical evidence.

The more conservative view is perhaps best represented by my own attempt (in 'National Welfare and National Decay'). In that book I have shown reason to believe that the various races of man differ in respect to the relative strengths of the several instinctive tendencies. That in one race the pugnacious tendency is very strong, in another weak, in a third of intermediate strength; and that the same is probably true of each of the great instinctive tendencies; so that we may attempt to characterise each race by the relative strengths or balance of the instinctive tendencies. Since individuals of the same race seem to differ from one another markedly in this way, there is *a priori* every probability that races should show similar differences. I argued also that these differences are reflected in the cultures and institutions of various peoples, and that the comparative study of such cultures and institutions is one great method by means of which we may hope to throw light on these racial differences.

This view, of course, is not incompatible with the advanced view taught by Jung; but it is very much more modest in its claims of racial mental peculiarities. I would say for myself that, while I regard the evidence for this conservative view as very strong, I cannot at present accept the advanced view, though my mind is open to conviction if more evidence should be forthcoming.

In addition, it may be said that both the advanced and the conservative view would recognise that just as there are undoubtedly wide innate differences between individuals of the same race in respect of such special mental capacities as musical and mathematical talent, power of visualisation and of concrete recollection, so also there are similar differences between the races of man. The fact that we are quite unable to imagine or describe in what these innate capacities consist, as latent hereditary disposition, is no ground for doubting their reality and importance.

15a. Dr. May Bere.—*Mental Differences of School Children of Foreign Parentage.*

This study attempts to determine the relation between nationality and mental capacity in children of Italian, Bohemian, and Hebrew parentage. To delineate more clearly the direct share of nationality in the production of mental differences, an effort was made to control as far as possible the effect of other factors that might influence the child's development—such as the social status of the parents, the language spoken in the home, and the length of residence of the parents in the United States.

A statistical analysis of the results with the Stanford Revision of the Binet-Simon Scale and the Pintner-Patterson Performance Tests shows reliable differences between any two of the nationality groups studied. These differences vary in size when variations as to social status and languages used in the home are eliminated, but significant differences still remain in nearly all cases. Measured by the Stanford-Binet the groups rank as follows : Hebrew, Bohemian, and Italian ; while on the Pintner-Patterson the order is changed to Bohemian, Italian, and Hebrew, indicating the importance of using a wide variety of tests for the just evaluation of groups.

Tuesday, August 12.

16. Prof. C. Spearman, F.R.S.—*Shapes or Relations?*

The study of sensory perception has recently centred in the theory of 'shapes' (*gestalten*), taking this word to include not only spatial forms but also by analogy such characters as movements, melodies, colour-schemes, and so forth.

This theory—introduced in place of the obsolete doctrine of associationism—has split psychologists into two opposing camps. The one side maintains that perception commences with sensations and then continues with an act of 'intellect' or 'attention' which reveals relations. But the other side denies any such doubleness of operation ; it asserts that the shapes or 'configurations' are perceived as immediately as the sensations and even the relations themselves.

Now, both contending parties must be charged with certain untenable views. The 'intellect,' 'attention,' &c., are in truth but degenerate survivals of the old 'faculty psychology.' The controversy engaged in by both sides as to whether relations have any 'real existence' is an unnecessary, unfruitful, and hackneyed excursion into metaphysics. The configurationists are further guilty of overlooking that, even if sensory perception cannot be split into any sum of concrete processes, it may still be analysed into a system of abstract constituents. In point of fact, such abstract analysis is necessary in all science whatever, and is indispensable for the adequate comprehension of any perceptual shapes. Putting aside these aberrations of both schools, there still remains the vital question as to whether sensory perception essentially involves two processes or only one. Here, the configurationists are perfectly right to insist that—in many cases, at any rate—the entire shape seems to be given in an immediate manner, and that the division by their opponents into two steps has been an *à priori* construction unsupported by scientific evidence. In order to obtain such evidence, there is only one legitimate procedure. This consists in reducing all observable cognitive operations to their ultimate *laws*. Once established, these laws can be applied, not only in predicting the future, but equally well in revealing the past. One of these laws is that cognitive items tend to evoke a perception of their inter-relations. At early stages of development, then, a person's sensations must have been less clearly and richly inter-related ; at the limit, they were perhaps wholly unrelated. Again, another of these laws is that experiences tend to evoke a cognition of their nature. At the primitive stages, then, a person's sensory experiences must have been less distinct ; at the limit, perhaps, they may well have been wholly obscure and uncognised.

In this manner, genetic considerations of the sole legitimate kind result in supplementing the incomplete statements of the monists and in amending the inaccuracies of the actists.

17. Dr. J. T. MacCurdy.—*The Psychology of Déjà Vu.*

The work of Grasset, Freud, and others has shown that *déjà vu* is caused by activation of an unconscious memory of a real event, a fantasy, or a dream, which in some way resembles the co-incident, conscious perception. This memory, although stimulated, does not enter consciousness as such, but affects it only as an obsessive feeling of familiarity. A newly described group in manic-depressive insanity—the perplexity cases—are characterised by a peculiar affect closely analogous to the feeling of *déjà vu*. In studying this condition the mental processes, which result in this subjective perplexity, are easily discovered. We are thus enabled to see the mechanism of production of *déjà vu* and, in turn, to understand more fully the nature of normal recognition.

18. Dr. E. Mayo.—*Reverie and Industrial Fatigue.*

19. Dr. C. M. Hincks.—*Mental Hygiene as a National Enterprise.*

20. Prof. C. S. Yoakum.—*The Definition of Personality.*

An effort to formulate a definition of personality which would enable the psychologist to proceed experimentally in this field as he has done in the fields of sensation or perception would be of value. The following definition is proposed : *Personality* is that combination of behaviour forms in the individual which during the process of individuation distinguishes that individual from others of a group.

21. Prof. J. P. Porter.—*A Comparative Study of Ideational Processes and Intelligence.*

22. Dr. A. A. Roback.—*Some Phenomena of Graphic Interference.*

Problem.—To discover both conscious and unconscious experiences attendant on writing from dictation at a steadily increased speed.

Method.—Twenty-two subjects were used. The stimuli-words or other symbols were made known to the writers so as to avoid mishearings. Distraction was not introduced.

Results.—The course of least exertion, previously reported in 'The Interference of Will-Impulses' manifested itself in slips of various kinds (anticipations, repetitions, substitutions, omissions, and combinations), automatic and meaningless marks; but a very curious type of result was the *composite*, consisting of rudiments of two or more stimuli, but not resembling either. Most of the lapses and other phenomena are due to two processes in the nervous system, *assimilation* and *perseveration*. Very few lapses are attended by introspective consciousness—these being confined to anticipations for the most part. Other results are the slurring of vowels and favouring of initial letters as against final letters, and the degeneration of the handwriting to primitive strokes and dashes with increased speed. The introspective protocols offered some very interesting observations in connection with the nature of inhibition.

Wednesday, August 13.

23. Dr. J. Drever.—*Conscious and Unconscious in Psychology.*

Consciousness is not an entity, but a character or attribute belonging to certain processes. It is marked by 'psychical integration' and a peculiar 'inner view' of the event.

The 'unconscious' ought to mean always dispositional elements rather than mental processes. Mental processes of a different order from conscious processes ought to be designated 'endopsychic,' as, for example, the processes in the operation of associative bonds or in conflict.

24. Dr. Christine Ladd-Franklin.—*Theories of Colour Vision.*

References : Dr. Ladd-Franklin's Appendix to Vol. 2 of the English translation of Helmholtz's Physiological Optics, to be published by the Optical Society

of America, contains a full account of the Ladd-Franklin theory of colour vision. Dr. Ladd-Franklin's colour charts are to be issued by Stoelting & Co., Chicago.

The light-sensations are (in the order of development) :—

(*a*) White (including a dull white or 'grey');

(*b*) Yellow and blue added, but the yellow-blues revert to white;

(*c*) Red and green added, but the red-greens revert to the yellow out of which they were developed.

This is the great fundamental fact of colour-sensation. The two apparently incompatible facts, namely, chromatic sensations made up from three (Young-Helmholtz) or from four (Hering), become reconcilable according to the Ladd-Franklin development theory.

25. Discussion *on Colour Vision.*

SECTION K.—BOTANY.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 469.)

Thursday, August 7.

1. Discussion on *The Ascent of Sap and Transport of Food Materials in Trees.*

(*a*) Prof. H. H. Dixon, F.R.S.

Recent observations confirmatory of the cohesion theory of the ascent of sap. Renner's and Ursprung's measurements of the tensile strength of water. Holle's and Bode's demonstration of continuous water-columns in intact wilting plants. Bode's direct observations of the effects of tension in transpiring shoots.

Functions assigned to living cells in raising the sap. Ursprung's views. Actions of cells of leaves. Transpiration of dead leaves temporary. Secretion of water by cells. Energy supply.

Cohesion theory and transport. Carbohydrates, proteins, and enzymes in the transpiration-stream. Ringing. Changes in wood-parenchyma and tracheæ. Action of callus. Wood conveys organic substances upwards. Downward transport. Unsuitability of bast. Necessary velocity. Reversed current in wood. Transference of stimuli. Connections of growing and producing parts with storage organs. Introduction of organic substances into tracheæ. Local permeability-differences. Tension determines mass-movement of contents of tracheæ from any source to any sink. Function of bast and parenchyma. Association of bast and wood.

(*b*) Dr. O. F. Curtis.—*The Transport of Foods and Nutrients in Woody Plants.*

When ringing experiments were performed during the growing season, it was found that materials necessary for growth would not move up through the xylem past the ring. Analyses and cryoscopic determinations indicated that the movement of sugars and other solutes was interfered with by the ring. When, just previous to spring growth, rings were made at different distances from the tip, it was found that the growth above the rings was, roughly, proportional to the amount of food stored above the ring, and quantitative tests indicated that the upward transfer of carbohydrates had been interfered with. Other experiments showed that carbohydrates failed to move out of or into the xylem of a given region if this region were isolated, by rings through the phloem, from other tissues which would normally receive or supply these carbohydrates.

It was further found that the normal upward movement of nitrogen and ash constituents was interfered with when the phloem was cut, though the movement was not completely stopped. This occurred whether the ring was made in the early spring before new xylem and leaves were formed, or in mid-summer

after growth was practically complete. Evidence was obtained indicating that the influence of the ring on the upward movement of nitrogen was independent of its effect on the organic content of this part above the ring or on transpiration.

Experiments with spiral ringing and other special treatments give further evidence that foods and nutrients travel upwards and downwards chiefly through the phloem.

(*c*) Dr. D. F. MacDougal.—*Variations in Volume of and Movements of Liquids in Trees.*

Dendrographic measurements of several species of trees show that the trunks undergo variations in volume, which may be correlated directly with the transpiratory activity of green surfaces, which in turn varies with the width of the stomatal slits.

The period in which stomatal slits are widest is one of contraction of the trunk: closure of stomata is accompanied or followed by expansion of the trunks. Contraction of the trunks or stems of mesophytes and sclerophylls takes place in the daytime; contraction of flattened or cylindrical stems of cacti takes place at night and expansion in the daytime, in reverse of the occurrences in the more general type.

The time or hour at which these two phases of variation prevail changes with the season. At the time of maximum growth contraction in coniferous trees may begin within a half-hour after sunrise.

Such reversible variations are modifiable by changes in relative humidity, by defoliation, girdling, topping, or any agency which alters transpiration or rate of conduction; and are explainable on the basis of Professor Dixon's conception of the mechanism of the ascent of sap.

The upward path of moving solutions of a basic dye such as fuchsin is found to be in the wood formed within the previous two years; when two layers are formed in a season, conduction is chiefly in the one formed earlier. Whether the other layers are more available or suitable for the downward conduction of organic material is yet to be tested.

The amount of reversible variation in the diameter of a young pine may be 1 part in 170, in the upper part of a tree approaching maturity 1 part in 900; in the basal region 1 part in 1700; in a large root 1 part in 364. As this variation takes place chiefly in the outer wood, it is found that in such recently formed layers the co-efficient of expansion and contraction may be five to ten times greater than that of the trunk taken as a whole, as given above.

(*d*) Prof. J. H. Priestley.

(*e*) General Discussion.

Afternoon Excursion to High Park and Humber Valley.

Friday, August 8.

2. Presidential Address by Prof. V. H. Blackman, F.R.S., on *Physiological Aspects of Parasitism.* (Page 233.)

3. Dr. W. Robinson.—*On the Conditions Controlling Growth and Reproduction in* Pyronema confluens.

The generalisation of Klebs regarding the antithesis between vegetative growth and the appearance of reproductive structures in many fungi is found to hold for *Pyronema confluens*. The lateral, aerial branch-systems of hyphæ which give rise to the antheridia and oogonia arise in cultures after vegetative extension is checked at the margin of the medium. Whether the branch-systems referred to will develop into antheridia and oogonia and subsequently apothecia is determined by the composition of the medium, especially as regards carbohydrate and nitrogen, by the relations of the culture to light, and by the humidity of the atmosphere over the mycelium. No reproductive structures arise in the dark, but certain white bodies occur in positions comparable with the aerial branch-systems referred to. These white bodies, which are very rich

in fatty contents, later become dark coloured and then black, and obviously degenerate. Normal production of reproductive bodies is invariably preceded by the appearance of a pink pigment in the mycelium, and no pink pigment appears in darkness. The dependence of the hyphæ on light, both for the production of this pink pigment and also for the development of the reproductive bodies, suggests that possibly the two phenomena are causally connected.

4. Miss C. A. PRATT.—*The Staling of Fungal Cultures.*

The problem is considered from the point of view of the change brought about in a liquid medium (Richards' solution) by the growth in it of a fungus (*Fusarium sp.*). 'Staleness' of the medium is not due to exhaustion of food. The medium becomes alkaline, i.e. its pH value changes from 4.6 to about 8.6. This is mainly due to the accumulation of potassium bicarbonate. Now, in a medium of pH = 8.2 produced by potassium bicarbonate, growth is inhibited; potassium carbonate and potash have no sensible effect at this pH. Nevertheless, acidifying only partially restores the germinative capacity of the stale medium. Acidification liberates simple organic acids, metabolic products of the fungus. These acids are growth inhibitors, hence the poor growth in an acidified stale medium. The salts of organic acids are not toxic, i.e. are not active in the alkaline medium.

The 'staleness' of the medium, i.e. its loss of germinative capacity, is therefore ascribed to the accumulation of potassium bicarbonate due to carbon dioxide from respiration.

5. Prof. F. E. LLOYD.—*The Fluorescent Pigments of the Cyanophyceæ.*

It has previously been shown that the fluorescence of the blue-green algæ is microscopically observable in living material, that of the species containing phycocyanin as deep red, that of those containing phycoerythrin as orange, corresponding to our previous knowledge of the pigments involved. A third condition is here reported represented by a species of *Arthrospira* previously thought to be non-fluorescent (*Science*, II., 59, 241), but which is now found paralleled in pigment content by *Oscillatoria chlorina.* These two forms are both yellow-green by transmitted light and blue by reflected light (dark field condenser with inverted light cone). The *Oscillatoria* is blue-fluorescent in ultra-violet (fluorescence microscope). It is expected that a yellow, blue-fluorescent pigment will be found, and, if so, may be named phycoxanthin. The emplacement of these pigments will be discussed. (Illustrated by colour-process lantern slides.)

6. Prof. W. T. GORDON.—*The Structure and Relationships of the Genus Pitys.*

Report of Committee of Section C (Geology) to investigate the fossil flora of the Lower Carboniferous rocks as shown at Gullane, Haddingtonshire (East Lothian).

The Structure and Affinities of the Genus Pitys.—One ideal which the palæontologist keeps before him in describing fossil remains is to present to the mind a picture of the particular organism as a living, working machine. Such an ideal is, however, rarely realised. The fortunate discovery of some well-petrified plant-remains in a volcanic ash at Gullane has allowed this ideal to be realised to a large extent in the case of the genus *Pitys.*

It may not be without interest to recall to mind that the first fossil plants described from thin sections belonged to that genus, and that the types then recorded (Witham 1831) had attained the size of forest trees. At Gullane, in addition to fragments of such large trees, we have now to record the discovery of twigs, clothed with bark, and, in two instances, buds with their leaves attached. The results of the investigation were presented in a paper to the Royal Society of Edinburgh in June of last year.

While the discovery of the cortical tissues completes our knowledge of the general anatomy of the stem of *Pitys,* greater interest centres round the leaf structures. These undoubtedly indicate that the leaves were really only petioles.

and that no lamina was developed. Further, had they occurred detached from the stems, they would certainly have been described as petioles of a fern or of a pteridosperm. It is interesting to note, however, that in the development of the leaves of the modern form *Araucaria excelsa* we have a very close parallel to that now recorded in this Carboniferous genus *Pitys*; and relationships between these two forms are not beyond the realms of possibility.

7. Miss E. S. Dowding.—*The Regional and Seasonal Distribution of Potassium in Plant-tissues.*

This paper deals with the occurrence of potassium in plant tissues as shown by the hexanitrite of cobalt and sodium, a reagent previously employed by Macallum in microchemical work on plant and animal tissues. On examining plants of contrasting physiological types, a characteristic potassium distribution was noticed for nearly every tissue. In some tissues this substance is most abundant, for example, in the 'crown' cells below the spruce bud, and in the aleurone layer of the wheat grain, so that these tissues appear to act as storers of excess potassium. All meristematic tissues give a very dense reaction.

In recording the seasonal variation of potassium in *Picea canadensis*, it was found that towards spring there was an increase in the amount in the conducting tissue, a redistribution of potassium within the bud, and a variation in the manner of distribution within the mesophyll cells.

8. Mr. E. H. Moss.—*Parasitism in the Genus Comandra.*

The genus *Comandra* is represented in Canada by four species, of which at least three are semi-parasites with a wide distribution and an extensive range of host plants The haustoria by which the parasite is attached to the underground parts of its host are in general similar to those described for other Santalaceous species. In the Rocky Mountains, *Comandra livida* is characterised by the occurrence in large numbers of variegated and more or less dwarfed individuals. Histologically the leaves of these abnormal plants exhibit features which are typical of mosaic diseases.

9. Dean F. C. Harrison.—*The Miraculous Micro-organism.*

An historical account of the red pigmentation of foods from B.C. 332 to the present. The nomenclature of the organism. [Taken as read.]

10. Mr. J. L. Sager.—*Soil Acidity Investigations Conducted in Switzerland and Devon.*

Determinations of the pH of soil filtrates made by the colorimetric method have shown that a definite correlation exists between intensity of light and soil acidity

(A) *Grand St. Bernard Region* (gneiss, granite, schists)—alt. 1,100 to 2,700 metres.

The results show definitely that in passing from the deep shade of the Spruce Forest (pH 4.6) to the lesser shade of the Larch Forest (pH 5.1) and then on to the open, we pass successively through soils of less and less acidity. Where the light is intense low pH values are rare, except in two special instances where oxidation is necessarily deficient. These are (*a*) where the soil is shallow, matted, and compact, and (*b*) where the soil is constantly wet.

(B) *South Devon.*—(1) Blackheath Wood, near Kenn, on Permian Breccia—alt. 200ft. Deepest shade under *Prunus laurocerasus* bushes pH 5.4, under *Pinus insignis* 6.4, and in Pedunculate Oakwood 6.6 and 6.8.

(2) Stoke Woods, near Exeter, on Culm Shales—alt. 300 ft. Under *Pinus sylvestris* pH 5.1, Beech 6.0, Mountain Ash 6.3, and in Hazel Copse 6.7.

(3) Pine Woods on Black Hill, Woodbury Common (Budleigh Pebble Bed)—alt. 540 ft. Deepest shade under Holly bushes pH 5.2, *Pinus sylvestris* 5.7, *Pinus pinaster* 6.0, and edge of Wood at roots of *Erica cinerea* 6.3.

Monday, August 11.

11. Prof. E. C. Jeffrey.—*The Present Status of the Biogenetic Law.*

The Biogenetic Law, or the Doctrine of Recapitulation, is one which has been the subject of repeated attacks upon the part of mutationists and mechanists

in recent years. The peculiarities long known to exist, for example, in the embryos of the higher vertebrates are interpreted either as direct adaptations to embryonal environment or as representing merely larval phases which are of no real evolutionary significance. Recent studies carried on in the author's laboratories on the anatomy of Mesozoic conifers throw an interesting light on the situation. It cannot be claimed that the seedlings of the higher seed-plants, in particular the seedlings of the living conifers and dicotyledons, are in any sense larval in the signification of the term used on the zoological side. In the case of the conifers we are now in a position to compare the details of structure in the seedling of living forms with the mature organisation of their Mesozoic ancestors. By such comparison it is found that both in the Araucarian and Abietinean conifers, which at the present time are in competition for the place of the most primitive conifers, the seedlings of living forms supply an exact recapitulation of the organisation of these types in the Mesozoic. No more striking inductive evidence could be supplied for the truth of the doctrine of recapitulation, since inductive logic furnishes the basis of scientific reasoning.

A further interesting corollary of the doctrine of recapitulation, when studied in the light of the comparison of living with fossil forms, is that the root and reproductive axis also perpetuate ancestral conditions, and that these may also frequently be recalled by experimental means. The importance of this situation from the general biological standpoint is not open to question.

12. Dr. Ethel N. Miles Thomas.—*The Primary Vascular System in Phanerogams: its Characters and Significance.*

The results obtained in the investigations of the last twenty years on 'Seedling Anatomy' have been held to be conflicting and disappointing. This is largely due to false comparisons having been made as to fact and theory.

Seedling Anatomy considered as a branch of Comparative Anatomy probably furnishes more comparative data than any other part of the plant body and shows features of surprising constancy and widespread occurrence.

It is possible to make the following generalisations, founded on the comparison of more than 1,000 species.

In the great majority of species :—

1. The first formed primary strands of xylom and phloem are developed on separate radii in hypocotyl, root and cotyledon, so that they conform, throughout the plant body, to the alternate or radial rather than to the collateral arrangement. In this respect, at any rate, there is therefore no sharp distinction between the root and shoot anatomy in the earliest vascular system O X O (*see* Chauveaud, Thomas). The apparent exceptions are yielding to further investigations—Ricinus (Thomas, *Journal of Linn. Soc.*, 1922; Sapotaceæ, Thomas, *Brit. Ass. Rep.*, 1923; Monocotyledons, Chauveaud, 1921, Thomas, 1924).

2. The primary *radial* arrangement is obscured and even obliterated in most species by the disappearance of the alternate xylem at a very early age (one cause of false comparisons) and the production of *collateral* primary and secondary xylem, so that what may be regarded as a single vascular unit (double bundle or triad, Thomas, 1914) in the primary condition, appears as two units at a slightly later age.

O O (Cf. Scott, *Struc. Bot.*, Vol. I.)
X X (7th with later Eds.)

In the view of the writer this phenomenon undoubtedly accounts in most cases even for the two separate strands met with in the cotyledon of certain Monocotyledons (e.g. Cordyline) (Chauveaud).

Single (' double ') strands are found in the monocotylous Dicotyledons Ranunculus Ficaria, Anemone apennina, Conopodium denudatum, Cyclamen persicum, and this fact strengthens the above interpretation of the vascular strands of the cotyledon of true Monocotyledons.

Almost without exception in dicotyledonous forms and in a number of monocotyledons and pseudo-monocotyledons examined by the writer :—

3. The plane passing through two of the poles of the primary root passes also through the centre of the two cotyledons or one cotyledon (Cruciform type of Thomas). In the diarch forms it is these poles alone which are developed. In the monocotylous Dicotyledon *Conopodium denudatum*, however, the diarch plate is at right angles to

the centre of the cotyledon, and the same thing is found in a few true Monocotyledonous species. These frequently have incipient poles in the cotyledonary plane also.

Where the plane of the root poles does *not* (Diagonal type of Thomas) coincide with that passing through the centre of the cotyledons, the primary radial protoxylem elements, normally developed in the cotyledonary plane, though sporadically present, would seem to be disappearing phylogenetically as well as ontogenetically. The phenomena to be observed in the following species may perhaps be regarded as stages in this process: Calycanthus, Thomas 1914; Alnus cordifolia, Davey 1915; Sapotaceæ, Wright 1902, Thomas 1922; Acer pseudoplatanus, Holden and Bexon 1923.

4. The study of the hypocotyledonary region gives the truest picture of the fundamental anatomical structure of the seedling. The cotyledon strands may vary in number and constitution, in species which show identical hypocotyl structure, so that the number of cotyledon strands in no sense 'controls' the number of groups in the hypocotyl. Moreover, hypocotyl structure may be unaffected even by variation in the number of cotyledons developed. This is shown by comparison of Monocotyledons, Dicotyledons, Polycotyledonous Conifers, and in particular by Pseudo-monocotyledons (Thomas 1914) and Pseudo-dicotyledons (Coulter and Land 1914).

5. That the characteristic alternate grouping of cotyledonary and hypocotyl strands is not a 'transition' phenomenon—a 'carrying up' of root strands is shown by the presence of this grouping in the plumule (Thomas 1914, Davey 1915, Bugnon 1920, Holden and Bexon 1923) and by its production in the cotyledonary plane, even where root poles are developed only in the diagonal planes.

Conclusions: 1. That there is a remarkable uniformity in the main features of seedling anatomy, particularly as displayed in the hypocotyledonary region.

2. That this uniformity has been obscured by developmental changes, notably by 'resorption' (which converts a single '*alternate*' group into two collateral strands) and by errors in descriptions and conclusions, largely due to these changes.

3. That Van Tieghem's types should be abandoned. They no longer serve a useful purpose since they depend upon criteria (rotations and number of strands) which the work of the present century, when duly compared and considered, proves to be false criteria. The terms *cruciform* and *diagonal* may temporarily be allowed to distinguish the only important difference of position known. *Cruciform* connotes the almost universal production in the root of poles in the plane of the centre of the cotyledon and *Diagonal* the rare condition of the production of the root poles at 45° to this plane.

4. That the hypocotyl is the region of greatest constancy and that its alternate or radial structure is probably of phylogenetic import, and that the number of strands in the cotyledon and even the number and size of the cotyledons themselves bear little relation to the number of primary groups in the axis.

5. That the phylogenetic theories of Sargant, Thomas and Chauveaud stand for further consideration, but that the relation between Monocotyledon and Dicotyledon rests on the 'symmetry' of the hypocotyl and not on the suggested significance of the two central strands of the single cotyledon of Monocotyledons.

6. That Seedling Anatomy provides a new field for work in Embryology, Comparative Anatomy, Organography, and particularly for consideration of the relation between structure and function, Phylogeny and Ontogeny and Heredity and Environment.

13. Dr. A. B. Rendle, F.R.S.—*Early Botanical Exploration in British North America.*

14. Mr. R. D. Good.—*The Past and Present Distribution of the Magnolieæ.*

The paper is an attempt to review the pre-Darwinian hypothesis of climatic migrations, put forward by Prof. E. Forbes in 1845, in the light of our subsequent increase of knowledge. For this purpose a homogeneous and well-defined group of plants—the Magnolieæ—has been selected and its history and distribution carefully analysed and considered.

A short introduction, outlining Forbes' theory, is followed by some general remarks upon the systematics and biology of the group. Their general recent distribution is then described and is followed by detailed accounts of the individual genera. After this the influences of climatic factors are discussed. Next, the fossil record is considered, and this is followed by a survey of our know-

ledge of geological history as far as it affects these plants. At this point the case of Liriodendron, since it epitomises that of the Magnolieæ, is briefly sketched.

These various aspects of the subject are then brought into harmony, and the history of the Magnolieæ, as indicated by them, is postulated. The assumptions involved by the Hypothesis of Migrations are reviewed and their logical results indicated. Finally, the hypothesis is considered from the point of view of its value in helping to elucidate the present distribution of flowering plants in general, and the paper concludes with a comparative valuation of the Hypothesis of Migrations and the Hypothesis of Age and Area.

15. Miss E. R. Saunders.—*The Evolution of the Carpel.*

The current conception that carpels are all of one type representing an expanded folded leaf is inadequate and erroneous. Evidence is brought forward in disproof of this idea and in support of the view that a general tendency to reduction in number accompanied by a process of 'consolidation' has led to the evolution of several different carpel types. Polymorphism of this character is of almost universal occurrence among flowering plants, and is accompanied by separation and redistribution of the three carpellary functions (protective, receptive, reproductive). Many assumptions, quite unfounded but inevitable from the orthodox standpoint, now become unnecessary. Certain anatomical features hitherto devoid of significance acquire new meaning, and numerous apparent anomalies for the first time become intelligible and fall into line, as, *e.g.*, the *commissural* stigma, *true* obdiplostemony, *free-central* placentation, the occurrence of *supernumerary* styles and stigmas, *polymorphic* fruits, *reversed* orientation of the gynæceum, and many others.

16. Prof. D. Thoday.—*Some Aspects of the Richness of the Cape Flora.*

The richness of the Cape Flora is not a simple phenomenon. The following are factors which may have influenced it :—

(1) Climatic conditions keep the vegetation more or less open, reduce mutual competition, and so favour fuller registration of mutability.

(2) Conditions may have led to greater mutability, either through the variety of habitats provided or by directly inducing it. This is particularly suggested by the concentration of endemic species in the South-West Cape, especially large genera like Phylica, Erica, &c., and by the similar richness and endemism of the south-west part of West Australia.

(3) The origin of species has continued relatively undisturbed since Tertiary times. No reservoir of cold temperate vegetation exists to the south, and hence there has been no parallel to the devastating migrations during the Pleistocene in the Northern Hemisphere which must have wiped out particularly those species that were most highly specialised and confined.

17. Prof. F. J. Lewis.—*The Behaviour of Chloroplasts and other Cell-contents at Low Temperature.*

The changes in shape and position of the chloroplasts in the leaf cells of species of Picea, Pinus, Abies and Thuja at the Pacific coast are described. Comparison is made with the features present in conifers native to Alberta in the winter, observations being made on plants outside and others kept at greenhouse temperature.

The ability of the chlorophyll to carry on carbon assimilation while in the winter condition at laboratory temperatures is discussed on experimental evidence.

18. Joint Discussion with Section M on *Forest Problems.*

(*a*) Mr. J. W. Toumey.—*Recent Progress and Trends in Forestry in the United States.*

National, state, communal, and private enterprise all enter into recent progress in forestry in the United States. National forestry began earlier and has gone farther; state and communal forestry are of later development; private

forestry is in its first stage of development. Thirty-five years ago we had no public forests recognised as such and organised for continuous production. To-day we have about 165 million acres of national, state, and communal forests. The present trend in acquiring additional public forests by the nation, state, and community, and the temper of the public toward taxation, indicate that this acreage will not increase rapidly enough or go far enough to solve our forestry problem. All absolute forest land in the United States must be intensively managed for continuous yield before the annual growth will even approach our present annual consumption. Nearly four-fifths of our entire forest area is still privately owned. The public appreciates the necessity for the practice of forestry or privately owned forest land, and the trend of public opinion is toward the solution of this problem. One body of public opinion favours coercive measures, another favours co-operation. Recent tendencies indicate that the largest body of public opinion is toward co-operation and public assistance, which will make private forestry more attractive economically. This assistance centres in organised fire protection and tax adjustments. The past twenty-five years have seen a remarkable advance in forestry education and in forest research, both of which are of great importance in promoting private forestry, and already the view-point of private forest owners is changing toward sustained yield. Private forestry, what we as a nation do with our privately owned timber-land, is the only great forestry problem in the United States to-day. The establishment of processes for the efficient management of privately owned forest property and their orderly execution more than all else will determine our position in the future as a timber-producing country.

(*b*) Dr. J. M. Swaine and Dr. J. M. Munro.—*Forest Protection from Insects.*

Forest insect injuries in Canada have been responsible during the past fifteen years for enormous timber losses, amounting to hundreds of millions of dollars in value. The most important outbreaks in living timber have been caused by the following insects : The spruce budworm in Quebec and New Brunswick ; the western pine bark-beetles in yellow pine, white pine, and lodge-pole pine in British Columbia ; the destructive spruce bark-beetle in white and red spruce in parts of Quebec, Manitoba, and Saskatchewan ; the larch sawfly throughout Eastern Canada, extending as far west as Northern Alberta ; and the white pine weevil in Eastern Canada. There have been many others but little less destructive.

Control of extensive epidemics of forest insects can be effected by direct methods in the case of some outbreaks caused by bark-beetles and wood-borers ; but we have no satisfactory method, at present, of controlling defoliating insects in large forest areas. It is possible that the distribution of poisoned dusts from air machines may prove useful for this purpose in the future.

The control of forest insects forms an important part of silviculture, and forest entomologists are wisely attempting the solution of their most difficult problems through full co-operation with the technical foresters and botanists. Our forest insect injuries will be much less severe when North American forests come to be managed in accord with the principles of scientific forestry. The most serious problems in silviculture can be dealt with effectively only through a generous co-operation between technical and practical foresters, entomologists, botanists, and, often, investigators in other branches of Science.

(*c*) Mr. D. Roy Cameron.—*Forest Fire Protection in Canada.*

1. Reference to situation in Canada as presented by author in paper before British Empire Forestry Conference, Ottawa, 1923.

2. *Résumé* of work and report of Committee on Fire Protection at said Conference.

3. *Résumé* of work and findings of Conference between Federal and Provincial Governments on forest fire protection held in Ottawa, January 1924.

4. Definition of a proper forest policy for Canada, with particular reference to fire protection, in view of the above, under following headings :—

(*a*) Fire prevention ; (*b*) Land classification ; (*c*) Dedication ; (*d*) Concentration of protection ; (*e*) Slash disposal ; (*f*) Proper organisation for control.

5. Development of policy and administrative methods in Canada since British Empire Forestry Conference, and discussion as to how far such development is in line with proper policy.

6. Air operations :

(*a*) Present status; (*b*) Future possibilities.

7. Fire losses, 1923.

(*d*) Prof. J. H. Faull.—*Pathological Problems in the Forests of Eastern Canada.*

The key-note of forest pathology is protection from losses—whether as an aid to utilisation or to conservation. 'In the actual practice of forestry protection of the forest from its enemies is the first essential step' (Ralph S. Hosmer, in recent address). A knowledge of the factors of disease is fundamental; at the outset we are confronted in Eastern Canada with a multiplicity of diseases of which even the cause is unknown; this is revealed from studies on the diseases of white pine and the pulpwoods, some of the results of which are reviewed here. Throughout extensive areas of forest, mature or prematurely diseased following on injuries from fire or insect depredations, enormous quantities of timber (in some stands in excess of 50 per cent.) are left unharvested as being unfit; attention is being given to the possibilities of the utilisation of such timber; reference is made to experiments now in progress which indicate the likelihood that such losses may be partly avoided. From the standpoint of conservation, attention is being given (1) to the life histories of fungal parasites—studies that have an important bearing on the subject of sanitation, and hence on the spread of disease and on fire control, and (2) to the ages at which the hosts become susceptible to the attacks of various diseases—studies which have an important bearing on the problem of sustained yield.

(*e*) Mr. E. J. Zavitz.—*Forests and Forestry in Ontario.*

Of Ontario's total land area of approximately 407,262 square miles, 240,000 square miles may be classed as forest land. With a forest region so vast in area and running low in acreage yield, Ontario is confronted with a difficult problem in forest protection and administration.

About one-third of the acreage of this forest is of merchantable character, the remaining being either inaccessible or composed of areas of young growth.

Ontario is in a favourable position from the standpoint of the future development of forest policy, as the greater part of the forest area remains in the Crown, the timber-cutting rights only being leased. Of the forest area, approximately 23,000 square miles is dedicated and set aside as parks and forest reserves, although no real forest management has as yet been introduced.

Ontario's forests provide annual revenue to the State of approximately $3,000,000. The annual value of Ontario's forest products at the place of production totals something over $100,000,000, with an investment in mills and equipment amounting to over $200,000,000.

19. Dr. C. L. Shear.—*Life History and Taxonomic Problems in Botryosphæria and Physalospora.*

Certain species of these two genera of Pyrenomycetes, which are of wide distribution and great economic importance, show great similarity in their ascogenous conditions; but in their life histories they show remarkable differences.

Botryosphæria, as represented by *B. ribis* Gross. and Dug. on various hosts, has perithecia of medium size, usually aggregated in stromata with ascospores averaging 16-20 × 6-8 microns, which produce short, branched germ tubes, usually two. There are two forms of pycnospores produced, macro- and microspores. These are frequently found in the same stroma and are sometimes mixed in the same pycnidium. The pycnidia are of the Dothiorella type.

Physalospora, as represented by *P. malorum* (Berk), has larger perithecia, usually gregarious or in small stromata with ascospores very similar to those of Botryosphæria, but larger, averaging 30-34 × 7-12 microns, and producing long, unbranched, usually single germ tubes. The pycnidial form is of the

Sphæropsis malorum type. Small hyaline micro-pycnospores are also sometimes produced in the same or separate pycnidia.

Over one thousand single ascospore cultures of these fungi from various hosts have consistently produced one or other of the pycnidial forms mentioned, but never both. An active parasitic form of *Botryosphæria ribis*, first found on currant and producing serious blight, is only distinguishable at present by its parasitism and the production of a bright purplish pink colour on starchy media. This parasite, *B. ribis* forma *chromogena*, also occurs on Æsculus, Rosa, and *Pyrus malus*, as well as Ribes, as has been demonstrated by cross inoculations.

Both Botryosphæria and Physalospora are not infrequently found occurring, sometimes together, on the same host, and naturally they have been much confused in the literature.

This study indicates the need of a very thorough investigation of the morphology, physiology, and life history of such fungi in order to solve the many problems of taxonomy and pathology connected with them.

20. Prof. W. P. Thompson.—*Correlation of the Specific Characteristics in a Cross between a Durum and a Bread Wheat.*

21. Prof. B. T. Dickson.—*The 'Black Dot' Disease of Potato.*

The disease has been under investigation since 1921, and an account will be given from historical, geographical, symptomological, and economic points of view.

The organism isolated from Canadian material, with the saltation thereof, is described and compared morphologically and physiologically with *Vermicularia varians* Duco, *Colletotrichum tabificum* (Hall.p.p.) Pethy., *Colletotrichum* (Hall.p.p.) *atramentarium* (O. Gara) Taub., and *Colletotrichum atrovirens* (?).

Pathogenicity studies (still in progress) are reported.

22. Mr. C. W. Lowe.—*The Freshwater Algæ of Central Canada.*

22a. Prof. F. J. Lewis.—Popular Lecture on *The Vegetation of the Canadian Rockies.*

Tuesday, August 12.

23. Joint Discussion with Section D on *Species and Chromosomes.*

(*a*) Prof. R. Ruggles Gates.

When the 'Origin of Species' was written chromosomes were unknown, and until 1900 the history of the chromosomes was worked out quite independently of studies in heredity or evolution. Since that time the two fields of experimental breeding and cytology have become more and more closely interwoven, and future advances in genetics will depend upon the closer co-ordination of these two fields. The relative fixity in size, shape, and number of the chromosomes in a species is no longer disputed by those who know the facts. The changes which must have taken place in the chromosomes from species to species are only beginning to be studied, but important evidence of relationships can be gained in this way.

Comparative studies of the chromosome groups in many plants and animals lead to the recognition that phylogenetic chromosome changes have occurred in a variety of ways. These include polyploidy, or the development of higher multiples of chromosome numbers, transverse segmentation or fragmentation of certain chromosomes, end-to-end union of certain pairs, crossing of species with different numbers, and other changes.

In tetraploid mutations a new centre of stability arises. Hybrids with the parent form have an unbalanced chromosome number. They are largely sterile and their offspring revert to the parental types. Hence the condition of tetraploid mutations is essentially one of physiological isolation. This means the beginning of a new line of descent.

The study of chromosomes furnishes fundamental evidence in the tracing of phylogenies. It should be recognised by taxonomists as an essential element in the discrimination of genera and species.

(*b*) Dr. J. W. Heslop Harrison.

(*c*) Prof. Morgan.

(*d*) Mr. Julian Huxley.

(*e*) Miss K. Blackburn. — *Chromosomes and Classification in the Genera Rosa and Salix.*

Rosa is unique in the extent of its polyploid series built up on a base number of seven chromosomes. There is a first series with somatic counts of 14, 28, 42 and 56 which halve normally at the reduction division. Among these is *R. Wilsoni*, a hexaploid mutant arising in a similar way to the tetraploid form of *Primula Kewensis*. This type of polyploidy is also found in *Salix*, but, contrary to the condition in *Rosa*, has little systematic value, as it appears to have arisen separately in different sections, although probably also originating in hybridity.

In *Rosa* there are other series in which the terms diploid and haploid are not strictly applicable, since only some of the chromosomes pair at the reduction-division. There are two series, according to the number of chromosomes which pair. In the first of these, which comprises triploid, tetraploid, pentaploid, and hexaploid forms, seven chromosomes pair; and in the second, consisting of pentaploids and hexaploids, there are fourteen pairs.

Thus we have in *Rosa* two types of tetraploid forms and three of hexaploid.

That hybridity is really the cause of the whole series may be deduced by comparison with known hybrids such as Rosenberg's Droseras, and also from a study of *Rosa Wilsoni.*

(*f*) Mr. A. D. Peacock.

(*g*) Prof. Otto Rosenberg.—*A Cytological Basis for the Production of Species by Hybridisation.*

The number of chromosomes in a pure species is a balanced, diploid one. In a hybrid between parents differing in number of chromosomes such a balanced chromosome-number can be acquired in one of two ways. If the difference is in number of *sets* of chromosomes, the result sometimes will be normal heterotypic divisions and constancy in chromosome-number by 'allosyndese' and 'autosyndese.' In other cases by non-disjunction some extra chromosomes are present in the germ cells. In the heterotypic division of a plant produced by the union of two such germ cells it can happen that the extra chromosomes are homologous and able to conjugate, and it follows that the chromosome-number of its offspring will be constant and higher than the original parental number.

(*h*) Dr. E. C. Jeffrey.—*Polyploidy and the Origin of Species.*

(*i*) Prof. W. P. Thompson.—*The Deficiency in the Number of Chromosomes in a Dwarf form of Wheat.*

(*j*) General Discussion.

24. Prof. A. H. Hutchinson.—*The Age and Rate of Growth of British Columbia Trees in Relation to Ecological Factors.*

Graphs are given showing rate of growth as indicated by annual rings during the stages of youth, maturity, and old age under varying ecological conditions. The factors determining rate of growth frequently differ from those determining the age of maturity and decline.

Afternoon Excursion to Holland River Sphagnum Marsh.

Wednesday, August 13.

25. Joint Discussion with Section M on *Forest Problems in Canada.*

(*a*) Mr. R. D. Craig.—*Forest Utilisation in Canada.*

Since the earliest history of Canada the products of the forest have played a leading part in her economic development. Fur was at first the most important product; now the various wood products rank second in value only to agricultural products. During the years 1917 to 1921 the value of the primary products such as lumber, pulpwood, railway ties, &c., averaged $230,000,000 per annum. The further manufacture of these into pulp, paper, and other finished products added approximately $130,000,000 to the value, $70,000,000 representing wages paid to 56,000 workers. Exports exceeded imports by $195,487,000.

Canada is the principal source of saw-material in the British Empire. The annual cut of standing timber is about 2,600 million cubic feet. The lumber industry produced 3,800 million board feet of lumber, 625 million lath, and 2,880 million shingles, valued at $125,906,500. The pulp industry, including pulpwood and pulp exported and paper produced, contributed $146,891,481. Other products of the forest include 8,600,000 cords of fuel wood, 16 million railway ties, 14 million fence posts, 1 million poles, and large quantities of mining timbers, piling, &c.

One-third of the land in Canada, 1,200,000 square miles, is essentially forest land, capable under careful management of producing several times the present requirements of the industries, but as a result of fire, cutting, and other destructive agencies there remains only 456,000 square miles on which the timber is of merchantable size.

The total stand is estimated at 482 billion board feet of saw-material and 1,280 million cords of pulpwood, fuel, posts, &c., a total of 246,790 million cubic feet.

(*b*) Mr. E. H. Finlayson.—*The Facts and Possibilities of Silviculture in Canada.*

The paper traces the historical development of silvicultural practice in the Dominion forests and on the Crown lands in the various Provinces. It also explains the reasons for its absence in those Provinces that make no provision for the silvicultural treatment of their forests. The next stage in the presentation of the subject describes the silvicultural methods employed at the present time in the Canadian forests and in the reforestation of waste lands, together with the economic results of such operations so far as they have gone. And finally, the paper outlines the advisable courses of development in the future on the basis of the necessity of maintaining the continuous production of saw-logs, pulpwood, and the minor forest products.

(*c*) Dr. A. W. Borthwick.—*The Cultivation of Canadian Trees in other Countries.*

The introduction of tree species indigenous to Canada into European countries has added considerably to the value of the forest products of these countries. The value of Canadian species such as the Douglas fir and the Sitka spruce lies not only in the excellence of their timber, but also in their rate of growth and in their proved adaptability to British and Continental silvicultural conditions.

Among the pines, the lodge-pole pine is a most promising species. Characterised by hardiness to climatic conditions, non-exacting as to soil, and the utility of its timber. If the right race or type can be obtained it will prove to be a tree that will grow rapidly and produce timber of utility on sites where other species would prove to be uneconomic.

Abies grandis is the most promising silver fir as regards Britain for economic cultivation. *Tsuga albertiana* shows excellent growth and quality of timber, and it appears to have a pronounced adaptability for growth on peaty soils. *Pinus strobus* is excellently adapted to our silvicultural conditions, and it would produce timber of high technical value, but unfortunately the stem-blister rust meantime renders it useless as an economic unit in our list of forest trees.

(*d*) Mr. R. D. Craig and Mr. F. Storey.—*The Problem of the World's Timber Supply.*

Apart from fuel, usually obtained from hardwoods, an overwhelming proportion of the timber required for industrial purposes is produced by coniferous species (pine, spruce, &c.) which, with few exceptions, are limited in distribution to the North American continent, Northern Europe, and Siberia. These regions cannot be relied upon permanently as sources of supply. The position in Europe is unfavourable because timber consumption each year far exceeds forest growth. Siberian resources are to a great extent unexplored, but, as in Northern Russia, large areas of forest are likely to remain undeveloped owing to the difficulty and expense of extracting the timber. The United States consumes nearly half the world's production of timber, and it is feared that at the present rate of depletion the virgin forests of both the United States and Canada will not last more than twenty-five or thirty years.

In view of failing supplies and the slow growth of trees there is urgent need of reforestation of devastated areas, the protection of young growth, and the conservation of such of the original forests as still remain.

(*e*) General Discussion.

26. Dr. D. H. Campbell.—*The Relationships of the Anthoceratales.*

27. Prof. C. H. Ostenfeld.—*The Vegetation of Northern Greenland.*

SECTION L.—EDUCATION.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 469.)

Thursday, August 7.

1. Prof. G. M. Wrong.—*The Teaching of History and Geography of the British Empire.*

History moulds the traditions of a people; geography tends to determine their occupation, and with this, in part, their mentality. The British Empire manifests itself differently in five continents. There is no real New England anywhere. In every part of the Empire the British tradition is modified by local experience and by the influence of environment.

The teacher has to explain how the British Empire came into being, and why geography has made it so varied; why, for instance, a man of English descent in Canada, in Australia, and in South Africa is far from being an Englishman. Special sympathy and understanding are required to explain these differences. English history and literature are prevaded by the English climate. The English literature respecting Christmas requires explaining in Australia, where Christmas comes in the warm season. It is not easy for an Englishman, living within easy reach of the sea, to understand the problems of life on the Canadian prairie, hundreds of miles from the sea.

For effective teaching of history and geography each country requires an adequate literature, adjusted to the needs of the pupils in that country. It is probable that an Australian of understanding can write the history of England for Australians better than an Englishman, who would not comprehend the different angle at which an Australian must survey English history. The British Empire needs a copious literature, created not in one part but in all parts of the Empire. Another need is the instructive and sympathetic teacher, free from the patronising assumption that the best and truest are to be found only in his part of the Empire. A world-Empire needs a world-spirit in its teachers.

2. Mr. Ernest Young.—*Modern Tendencies in the Teaching of Geography.*

The teacher of geography should regard his subject as a preparation for a sane and sympathetic outlook upon the peoples and problems of the world. Geography, taught on sensible lines, is the foundation of rational internationalism, balanced patriotism, and efficient citizenship. The method of laying the foundation is (1) to deal with the whole world in the course of the school life, and to deal with it as a coherent whole and not as a number of independent and disconnected fragments; (2) to treat it as a collection of interdependent 'natural regions'; and (3) to give to each region a human interpretation.

School schemes in geography need to be as carefully organised as schemes in arithmetic, and to be characterised by progressive difficulty of ideas as well as by increased number of facts.

3. Report of the Committee upon *The Educational Training of Boys and Girls in Secondary Schools for Life Overseas.* Discussion opened by Sir John Russell, F.R.S., and followed by Miss E. H. McLean, Principal Harrison, Inspector F. P. Gavin, Mr. G. Fletcher, and others.

4. Dr. Ernest MacMillan.—Canadian Music, in the Hart House Theatre, University of Toronto.

Friday, August 8.

5. Presidential Address by Principal Ernest Barker, on *The Nature and Conditions of Academic Freedom in Universities.* (Page 247.)

6. Mr. A. E. Heath.—*Modern Developments in the Method and Scope of Adult Education in Great Britain.*

A preliminary survey of adult education in the nineteenth century. The value of its failures as laying bare the necessity for a broader educational basis on which to build. University Extension; the Workers' Educational Association; other organisations for adult education. The Tutorial Class system.

The nature of the problem involved in adult, as contrasted with adolescent, education. The methods of attack which have been developed to meet its special difficulties or to make the fullest use of its peculiar advantages. Influence of these methods on university teaching. The ex-Service-man student. Could the university age be raised with advantage? The choice of subject in adult classes. Main tendencies in such choice in recent years, and some inferences from them.

Widening the scope of adult education both in intension and in extension. Rural classes; holiday courses; correspondence courses. The Adult Education Scheme of the Prison Commissioners. Some recent proposals for co-ordinating the further work of students.

7. Dr. C. W. Kimmins.—*Sense of Humour in Children.*

Monday, August 11.

8. Joint Discussion with Section J on (*a*) *Tests for Scholarships and Promotions.* Principal E. Barker, Dr. C. Burt, Prof. G. M. Whipple, Prof. B. R. Buckingham.

(*b*) Prof. P. Sandiford, Messrs. Brennand and Holmes.—*The Use of Partial Coefficients of Correlation in Educational Research.*

(*a*) Dr. C. Burt.

I. Psychological tests for use in schools may be broadly classified as follows :—

(A) *Tests of Inborn Intellectual Capacity.*—(1) Tests of general intelligence. (2) Tests of special aptitudes.

(B) *Tests of Acquired Attainments.*—(1) Tests of educational attainments. (2) Tests of vocational attainments.

Tests of the foregoing types may be cross-classified according to procedure, as (*a*) written group tests, (*b*) individual oral tests, (*c*) individual performance tests.

II. Such tests may be used at various stages in the child's school career :—

1. *Tests for Departmental Promotion.*—In England most children are promoted from the Infants' Department to the Senior Department at the age of seven or eight. This is a neglected but crucial stage in the elementary-school child's life. His subsequent success in the scholarship examination may depend upon it. At this point the most valuable tests are individual and oral tests of general intelligence, such as the Binet-Simon Scale.

2. *Tests for Class Promotion.*—Within one and the same department promotion from class to class is likely to depend more upon attainment than upon capacity. Tests of acquired educational attainments are here, therefore, most serviceable to the teacher. Above Standard II. they may be administered by the group procedure.

3. *Tests for Transference to Central Schools and for Scholarships to Secondary Schools.*—Such transferences are generally arranged after a scholarship examination in educational attainments, such as arithmetic and English. To supplement examinations of the traditional type, however, group tests of general intelligence have of late been widely used in Great Britain.

4. *Tests for Entrance to Trade Schools.*—Here an over-emphasis upon attainments in English and arithmetic is apt to give a misleading result. Intelligence tests, particularly those of a performance type, would be of greater value. Tests for special aptitudes and for vocational attainments may be used for supplementary purposes.

(*b*) Prof. P. Sandiford.

Since Yule's determination of a general formula for the calculation of partial coefficients of correlation, comparatively little use has been made of it in educational research. Economists have used the method of partial correlations fairly freely in such studies as the prediction of crops and in the elucidation of the causal factors of pauperism. In recent years educators and psychologists have been trying out the method, and the results achieved by Gates, Burt, Prescott, Reavis, Franzen, and others have been most encouraging.

Partial coefficients of correlation enable the experimenter to find the independent contribution of each of several variables to a given result. In researches at the Ontario College of Education the scores made by pupils in specially prepared standard tests for High School Physiography and Physics were due not only to their knowledge of science, but also to such factors as reading ability, intelligence, age, and the like. By taking age into account and by use of tests for reading and for intelligence, followed by the calculation of partial coefficients of correlation, the experimenters were able to free the results from the influence of age, intelligence, and reading ability, leaving those mainly due to the knowledge of science. The method employed could be extended usefully in other fields.

9. Mr. C. M. Stuart.—*Modern Developments in Science Teaching.*

1. Science teaching up to about 1890, with special reference to the divorce between practical and theoretical teaching.

2. Importance of altering the course to ensure training in : (*a*) Observation and recording; (*b*) logical reasoning; (*c*) manipulation, all experiments to be done by the pupils; (*d*) quantitative work from the commencement; (*e*) no distinction between practical and theoretical work.

3. Modification of laboratories. For this purpose, plans of laboratories.

4. Courses for the above aims—hydrostatics, chemistry, etc. Invention of suitable experiments, need of arousing curiosity.

5. Description of experiments, more advanced work.

6. Success and failure of these aims; suggestions for the future development. Influence of examinations. Improvement in examinations needed.

7. Comparison with science teaching in other countries.

10. Prof. J. L. Myres.—*The Place of Classics in a Secondary School System.*

Training for participation in modern societies necessarily habituates the citizen-to-be not only to the outlook and manners transmitted from Teutonic and Celtic ancestors, but to our threefold heritage from other civilisations : the religious and moral experience in the Hebrew background of Christianity; Roman experience in law and public order; and the intellectual and artistic achievements of Greece. But whereas the Reformation's insistence on intimate acquaintance with Hebrew literature compelled and justified general recourse to translations, classical teachers postponed surrender of the traditional initiation into 'dead' languages, until this discipline, over-specialised at heavy cost to philosophical, historical, and scientific studies, was challenged by another heritage from the 'revival of learning,' the direct 'interrogation of nature' by systematic observation and experiment. In this reaction against 'classical' studies, indispensable elements of the 'humanities' lost their due place in the curriculum. But experience of strictly utilitarian training, and broader conceptions of citizenship, compel reconsideration of the educational value of our heritage from Greek and Roman experience, readily accessible now, like Hebrew thought, in adequate translations, but imperfectly appreciated, beyond the elementary stage, without progressive acquaintance with its original sources.

11. Mr. Arthur H. Hope.—*The Present Position of Classics in French Secondary Schools.*

The reform of 1902 under M. Georges Leygues instituted a scheme giving equal sanctions for the baccalauréat to four choices of programme : (A) Latin and Greek; (B) Latin and Modern Languages; (C) Latin and Science; (D) Modern Languages and Science.

Gradual reaction against this scheme, because of (*a*) premature choice of young boys between Classics and Modern studies; (*b*) the steady decline in knowledge of their own language of boys who were 'Latinless'; (*c*) the tendency of the modern programmes in particular to give an encyclopædic smattering of too many subjects; (*d*) the growing conviction that a full literary training should precede all scientific specialisation; (*e*) the belief that Section D duplicated the work of the 'Professional' Schools.

Reform of Programme, already overdue, postponed by war, then stimulated by national feeling which laid stress on the traditional French Culture, with its roots in knowledge of Latin.

The rehabilitation of the Classics, the work of M. Léon Bérard, Minister of Public Instruction, in December 1923, instituted (*a*) a single course for all boys, between the Sixth and Third Forms, including Latin in all four years and Greek in the last two; (*b*) a pre-baccalauréat test, success in which alone allows a boy to proceed to the two following years' study. In these two years which prepare for the first part of the baccalauréat a choice is given between (A) Latin and Greek; (B) Latin and Modern Languages; (C) Modern Languages alone. In all three sections the time given to Mathematics and Science remains the same. Opposition to this programme, only partly in operation, based on both educational and political grounds.

Tuesday, August 12.

12. Sir Robert Falconer, K.C.M.G.—*The Canadian University.*

The Canadian University has developed in accordance with local conditions into an individuality of its own. This has been due partly to its history. The political struggles of the various provinces are in measure reflected in the character of the several institutions. The stream of largest influence has been from Great Britain.

Except in minor instances, until the Universities of the Western Provinces arose very little American influence is traceable. The character of the Canadian University is due to the first professors, who came from Britain—Oxford, Cambridge, Edinburgh, and Dublin have been the most influential. The Canadian Universities since their origin have had an uninterrupted flow into them of British academic life. Its extent is manifest in the methods of teaching and the curricula, whether in Arts or the professions.

The British honour and pass system has been transferred to the Arts faculties; the examination instead of the recitation method prevails. The American influence is seen, however, to some extent in the athletic and social customs, and in the presence of chapters of American Fraternities the headquarters of which are in the United States.

13. Hon. Dr. H. J. Cody.—*The Administration of Education in Canada.*

The history and character of the administration of education in Canada; the basic difficulties of the administrators due to (1) the vast extent of the country with an average population of only two per square mile, (2) the varied character of the population, (3) the diversity of religious belief, (4) newness of the country, the modern era of Canadian history only beginning with the completion of the C.P.R. in 1885; the great administrative problems of Canada being the organisation and maintenance of schools in sparsely settled districts, and among foreign peoples of different nationalities, the influences that have moulded Canadian education and made it a provincial and not a Dominion concern.

In Ontario the most interesting of all problems was that of providing secondary education for all children. The Adolescent School Attendance Act, as part of the attempt to solve the problem, aims to secure for every child the right to a full development of his endowments, and to guarantee to society a fair measure of return in service for the expenditure on his education.

14. Dr. S. B. Sinclair.—*The Selection of Pupils for Auxiliary Classes.*

The paper discussed the question to what extent it is possible and desirable to utilise the local school staff in conducting school surveys. It contained the results of recent surveys conducted by the Ontario Department of Education, in which the preliminary general selection of pupils for special classes has been made by the local school staff—inspector, principal, teacher, nurse, and physician.

It described the procedure by which the staff selects about twice the number to be assigned to the special class, for subsequent examination by specialists.

It suggested methods of study and observation for the purpose of making an approximate estimate of mental age without giving a formal intelligence test, and gave the results of an experiment conducted for the purpose of determining how closely the teacher's approximation (after such preparation) coincides with the findings of an examination by a formal test.

15. Major J. B. Cowles.—*The Working of the Adolescent Education Act in Ontario.*

The Adolescent School Attendance Act, 1919, by which the compulsory school age is raised to sixteen years, is the result of a demand for vocational as well as for broader general education.

The enforcement of the Act is not meeting with serious objection, though in 1923 a disburdening amendment was made by the Farmer-Labour Government to appease certain farmers.

Enforcement, which is gradual, is satisfactory to the extent that school attendance departments have been organised and all adolescents fourteen and fifteen years of age are in full-time attendance at school or usefully employed. Increase in attendance in the elementary schools has been marked, while more than 30 per cent. of all young persons of the province are actually proceeding into the secondary schools.

Part-time instruction for exempted adolescents is being provided in certain cities, and plans are being formed in others where such instruction is necessary.

SECTION M.—AGRICULTURE.

(For references to the publication elsewhere of communications entered in the following list of transactions, see page 469.)

Thursday, August 7.

1. Hon. John S. Martin, Minister of Agriculture for the Province of Ontario.

2. Dr. F. T. Shutt.—*The Influence of Cropping on the Nitrogen and Organic Matter Content of Western Prairie Soils.*

The author discusses the influence of various crop rotations on the nitrogen and organic matter content of western prairie soils as exerted over a period of eleven years. Series of plots were set out at three Experimental Stations in Western Canada in 1910-11, soil samples collected and analysed, and the plots placed under different crop rotations. At the end of eleven years soil samples were again taken from the plots at the former points of collection.

The data—chemical and field—are recorded and inferences drawn as to the apparent effect of cropping and cultural treatments on the plant-food content—more particularly that of nitrogen and organic matter.

3. Mr. H. J. Page.—*Nitrogen Balance in the Soil.*

Recent work at Rothamsted and elsewhere on the nature of the different factors concerned in the nitrogen cycle in the soil is described. The interaction of these factors is discussed, with special reference to the total nitrogen content of the soil of the plots on Broadbalk Field, Rothamsted. The factors responsible for the immobilisation of the greater part of the nitrogen of the soil are discussed, special attention being given in the present paper to the chemical and physico-chemical aspects of the subject; the biological aspects will be discussed by the author in his contribution to the Joint Discussion with Section D on Soil Population.

Friday, August 8.

4. Joint Discussion with Section D on *Soil Population.*

Speakers: Mr. D. Ward Cutler, Dr. N. A. Cobb, Dr. A. E. Cameron, Mr. H. J. Page, and others.

5. President J. B. Reynolds.—*Agricultural Education in Canada.*

(*a*) Three Directions for Agricultural Education:

1. Vocational training for the business of farming.
2. Education for agriculture and country life.
3. Education through agriculture for a common citizenship.

(*b*) Subjects :

1, 2, and 3 are vocational; 4, 5, and 6 are the corresponding technical sciences.

1. *Farm processes:* The cultivation and management of the soil; the selection, breeding, feeding, management of farm crops; the selection, breeding, feeding management of farm stock.
2. *Economics:* Selection of forms of production to suit markets; cost of production—interest or rent, labour, maintenance charges; marketing—preparation of material and modes of marketing.
3. *Country life:* Conserving rural factors of civilisation; recreation, schools, churches, social and economic organisations.
4. *Agricultural Science:* Natural sciences, for the improvement of the soil and of domestic plants and animals, and the control of pests and diseases—bacteriology, botany, chemistry, entomology, genetics, animal and vegetable pathology, physics.
5. *Economic Science:* Political Economy and farm management.
6. *Social Science and Civics.*

(*c*) Ways and Means.

Obviously, the selection from this mass of material of subjects to be taught will depend upon several conditions—the capacities of the students; the requirements of the students, whether for vocational training or technical education; the equipment of the school and consequent ability to handle technical subjects illustratively, or vocational subjects practically; and the knowledge and training possessed by the teachers.

Short Courses.—These short courses are conducted at chosen points in country districts and at agricultural schools and colleges. They vary in length from one week to six months, and cover practically all agricultural subjects that can be demonstrated, such as judging live stock, judging and cleaning seed, fruit and vegetable growing, bee-keeping, dairying, poultry, gas-engines and tractors.

The short course is probably the most intensive method of presenting single subjects for vocational purposes.

Public Schools.—Here the chief purpose is educational, while vocational training is incidental. Agriculture in the public schools gives some opportunity for handling hoes and rakes; working the soil and raising crops; feeding calves and raising chickens (as home projects). As an educational subject it offers material for Nature study and natural science, and incidentally for history, geography, and arithmetic. Also, the teacher who is alive to the opportunity can show how interesting and varied is the work of the farm compared with the work of the factory or the office, and how important is agriculture in the economic well-being of the country. Important elementary lessons in civics and social science can be gathered from rural social conditions and rural organisations and methods of government.

High Schools.—Canadian high schools have been resolved into preparatory schools for the professions. The teaching of agriculture in the high schools has not made much progress (1) because agriculture has not been recognised as a profession; (2) because high school teachers have not been qualified to teach agriculture.

The raising of the standard of admission to agricultural colleges, to the extent of requiring matriculation, has accomplished, or will ultimately accomplish, two objects: the recognition of agriculture as a profession, and the inclusion of agriculture as a high school subject for matriculation and teachers' certificates.

When we speak of agriculture as a profession, we do not mean practical farming. That is a business occupation. We mean those occupations offered in journalism, agricultural teaching and research, and the many positions in the public service under the political departments of agriculture in the provincial and federal governments.

Agricultural Schools.—There are in Canada a number of schools that offer agriculture as their main subject along with certain academic subjects that go with a general education. There is one at Truro, N.S.; one or more in Quebec; one at Kemptville, in Ontario; and there are six in Alberta. These

schools aim principally to give a knowledge of scientific agriculture to practical farmers, not to prepare for the profession of agriculture. It would be in the nation's interest if a number of the rural high schools would introduce agriculture similarly as one of their main subjects, and become agricultural high schools.

Agricultural Colleges.—The provinces of British Columbia, Alberta, Saskatchewan, Manitoba, and Ontario have each an agricultural college. There are two and perhaps three institutions in Quebec teaching agriculture that are of college grade. One of these provincial colleges, Ontario, is a separate institution. The others are faculties of universities in the provinces.

These colleges have evolved in accordance with a general demand for professional training in agriculture, and the majority of their graduates become professional men in the public service.

The Task.—The tasks confronting agricultural education are ultimately these :—

1. To secure on the farms of Canada the continuous use of the best-known farming practice.

2. To maintain conditions of rural living satisfactory to those who are intelligent enough to farm well, and generous enough to live well and to be good citizens. For it is recognised that the material and the social well-being of the nation are dependent upon the character of the people who work and live in country places

Monday, August 11.

6. Prof. H. Barton.—*The Status of Animal Breeding in Canada.*

7. Prof. R. A. Berry.—*The Chemistry of the Oat Crop.*

8. Dr. J. B. Orr and Mr. W. Godden.—*Modern Aspects of Mineral Metabolism in Farm Animals.*

A general account of certain investigations on the mineral metabolism of farm animals, recently conducted at the Rowett Research Institute. On the basis of the conclusions from these experiments attention is drawn to the importance of the functions performed by the minerals in the animal body, to the extent to which farm animals are liable to suffer from deficiency of them and to the effect of such deficiencies both on the rate of growth of and the onset of disease in animals. Evidence is produced to show that it is not sufficient to consider the absolute amount of one or more of the mineral constituents of a ration, but that attention must be paid to securing a proper physiological balance between the different mineral constituents. It is further shown that, under certain conditions, the absorption and retention of some of the mineral constituents, more particularly of calcium and phosphorus, may be materially affected by varying the amounts of certain of the organic constituents of the ration. Attention needs to be paid not only to those inorganic constituents of foodstuffs which may occur in comparatively large amounts, but also to some of those, such as iron and iodine, which, although never present in large amounts, may nevertheless have a very marked influence on the health and well-being of the animal.

9. Presidential Address by Sir John Russell, F.R.S., on *Present-day Problems in Crop Production.* (Page 256.)

10. Joint Discussion with Section K (*q.v.*) on *Forest Problems.* (Page 449.)

Tuesday, August 12.

11. Joint Discussion with Section F on *Diminishing Returns in Agriculture.*

12. Mr. R. A. Fisher.—*Incidence of Rainfall in Relation to the Wheat Crop.*

13. Dr. G. P. McRostie.—*Some Forage Crop Needs and Difficulties in Canada.*

14. Mr. F. L. Engledow.—*A Spacing Experiment with Wheat.*

The experiment was one of a series aimed at the identification of those characters of different wheat forms by which their yielding capacities are mainly controlled. True plant characters—the vital processes—are not sufficiently understood to be the subject of such an inquiry. Consequently 'algebraic characters' like tillering and ear size were observed. Such characters are much affected by inter-plant spacing, and that is the first ground of necessity for making spacing experiments. The second is the fact that field crops, inevitably, are aggregates of a great number of spatial intervals. Plant growth and yield in the field consequently must depend largely upon the adaptability of each particular wheat form to the various spacing intervals encountered in field crops.

Two wheats were grown each at five spacings, and special measures were taken to secure uniformity of material.

Analytical data are produced to show that :—

1. The variability of yield per plant and yield per unit area with spacing can be resolved in terms of tillering, ear size, and grain size.

2. Ear size and grain size bear distinctive relations to tillering which are characteristically different in the two wheats.

3. Data of the kind discussed appear to offer an approach to the differences in yielding capacity displayed by the various forms of wheat in the field. Upon the discovery of these differences must depend the possibility of breeding higher yielding forms by orderly 'synthetic' aggregation of desirable characters by means of hybridisation.

15. Dr. G. Scott Robertson.—*Field Experiments with Rock Phosphates on Soils Poor in Phosphoric Acid.*

The paper gives an account of a number of field experiments carried out in the six counties of Northern Ireland to ascertain the fertilising value of ground rock phosphates compared with high grade basic Bessemer slag and superphosphate.

The experiments were carried out during the years 1921, 1922, and 1923, and are still in progress. The crops were turnips, potatoes, oats, and hay. The results show that on the turnip crop as good returns may be expected, on all but peaty soils, from ground rock phosphates as from superphosphate or high-grade slag. Contrary to expectations, superphosphate proved the most effective type of phosphate on peaty soils. On potatoes superphosphate proved to be decidedly the better phosphate. On the oat crop the best returns were given by basic slag, rock phosphate and superphosphate being equally good and not far behind the slag.

The experiments confirm the view that ground rock phosphates may, under the soil and climatic conditions of Northern Ireland, be regarded as an effective substitute for the rapidly disappearing high-grade basic slag. It is possible that the effectiveness of rock phosphates on the potato crop may be enhanced by still finer grinding.

Wednesday, August 13.

16. Joint Discussion with Section K (*q.v.*) on *Forest Problems in Canada.* (Page 454.)

REFERENCES TO PUBLICATION OF COMMUNICATIONS TO THE SECTIONS

AND OTHER REFERENCES SUPPLIED BY AUTHORS.

Under each Section, the index-numbers correspond with those of the papers in the sectional programmes (pp. 358-463).

References indicated by 'cf.' are to appropriate works quoted by the authors of papers, not to the papers themselves.

General reference may be made to the issues of *Nature* (weekly) during and subsequent to the meeting, in which resumés of the work of the sections are furnished.

Section A.

1. Cf. 'The Spectrum of trebly-ionised Silicon,' in *Proc. Roy. Soc.*, **103**, p. 413; further material to be published in the same.

2. Paper under same title to be published as bulletin of Nat. Research Council, U.S.A. Cf. 'Soft x-rays from arcs in gases,' *Bureau of Standards Sci. Papers*, No. 425; 'Enhanced spectra of Na and K in the low voltage arc,' *Astrophys. Journ.* **55**, pp. 145-161 (1922).

4. Cf. *Phil. Mag.*, **47**, p. 257 (1924); *Proc. Camb. Phil. Soc.*, 22, p. 253 (1924); E. A. Milne in *Phil. Mag.*, **47**, p. 209 (1924).

8. *Journ. Optical Soc. Amer.*, **7**, pp. 583, 913; *Amer. Journ. Physiol. Optics*, **5**, July, Oct.

11. Cf. 'Transmission of Sound by Flexible Materials,' *Amer. Architect*, Sept. 28 and Oct. 12, 1921; 'Nature and Reduction of Office Noises,' *ibid.*, May 24, June 7 and 21, 1922; 'Transmission of Sound by Masonry Partitions,' *ibid.*, July 4, 1923.

12. *Nature*, Nov. 8, 1924, p. 684.

15. Expected to be published in *Phil. Mag.* Cf. *ibid.*, Oct. 1913; *Franklin Inst. Journ.*, Nov. 1920; *Phys. Rev.*, Apr. 1922; *Trans. Roy. Soc. Can.*, 1922, 1923.

20. To be published in *Monthly Weather Review*.

21. A paper to appear shortly in *Geofysiske Publikationer*, Kristiania; cf. *ibid.*, **1**, no. 2; **2**, no. 3; **3**, no. 1.

23. Cf. *Phil. Trans.*, **221**A, pp. 239-264 (1920).

26*a*. Cf. 'Structure of Aragonite,' in *Proc. Roy. Soc.*, A, **105**; 'Refractive indices of Calcite and Aragonite,' *ibid.*; 'Influence of Atomic Arrangement on Refractive Index,' *ibid.* **106** (1924).

26*c*. Cf. Müller in *Trans. Chem. Soc.*, **123**, p. 2043; Shearer, *ibid.*, p. 3152; Müller and Shearer, *ibid.*, p. 3157 (1923); further results to be published, *ibid.*

26*d*. Cf. 'A Theoretical Calculation of the Rhombohedral Angle of Crystals of the Calcite Type,' in *Proc. Roy. Soc.*, A, **106** (1924).

26*e*. Cf. (for first part) *Phil. Trans.*, A., **224**, pp. 251-257; second part to be published, *ibid.*

28. *Journ. Soc. Chem. Ind.*, Aug. 29, 1924. Cf. *Reports* of Advisory Committee on Atmosphere Pollution.

30. To be published in *Monthly Weather Review*, and *Trans. Illuminating Engineering Soc.*, N.Y. Cf. H. H. Kimball and I. F. Hand, 'Sky-Brightness and daylight illumination measurements,' *Monthly Weather Review*, **49**, pp. 481-488 (Sept. 1921); *Trans. Illuminating Eng. Soc.*, **16**, pp. 255-283 (Oct. 10, 1921); 'Daylight illumination on horizontal, vertical and sloping surfaces,' *Monthly Weather Review*, **50**, pp. 615-628 (Dec. 1922); *Trans. Illuminating Eng. Soc.*, **18**, pp. 434-474 (May, 1923); H. H. Kimball, 'The determination of daylight intensity at a window opening,' *Trans. Illuminating Eng. Soc.*, **19**, pp. 217-234 (Mar. 1924).

31. To be published probably in book form with other papers.

34*b*. To be published in *Journ. Phys. Chem.*, *s.n.* C. Sweitzer. Cf. Kenrick, 'Scattering of light,' in *Trans. Roy. Soc. Can.*, **15**, 48 (1921), and *J. Phys. Chem.*, **26**, 72 (1922); Wismer, 'Pressure-Volume relations, etc.,' in *Trans. Roy. Soc. Can.*, **15**, 48 (1921), and *J. Phys. Chem.*, **26**, 301; Gilbert, 'Superheating, etc.,' in *Trans. Roy. Soc. Can.*, **15**, 53 (1921); Wismer, 'Supersaturation of gases, etc.,' in *Trans. Roy. S. Can.*, **16**, 271.

34*c*. To be published in *Journ. Phys. Chem.* Cf. *Journ. Phys. Chem.*, **24**, p. 478 (1920); **26**, pp. 75, 471 (1922); **27**, p. 558 (1923); *Trans. Roy. Soc. Canada*, **16**, iii, p. 276 (1922); **17**, iii, p. 151 (1923).

35. A paper on the subject to be published in *Phil. Mag.*

36. Main portion to be published in *Journ. Franklin Inst.*

37. Cf. 'The 27-day Period (Interval) in Terrestrial Magnetic Disturbance,' *Proc. Roy. Soc.*, A, **106**, pp. 19-32 (1924); 'The Magnetic Disturbance, 1924, January 29-30,' *Monthly Notices R.A.S.*, **84**, pp. 531-532.

38. To appear in *Publications of Dominion Obs.*, and probably in *Journ. R.A.S.C.*

48. *Publications of Dominion Astrophys. Obs.*, **3**, no. 1.

49. To appear as *Publications of Dominion Obs.*, **9**, no. 2; cf. *ibid.*, **5**, no. 7; **8**, no. 4; *Lick Obs. Bull.*, **9**, p, 173.

50. To appear in substance in *Publications of Dominion Obs.* Cf. *Pub. Amer. Ast. Soc.*, **4**, pp. 185, 237, 390; *Journ. R.A.S.C.*, 1922, p. 121; 1923, pp. 10, 79, 109, 247, 383; 1924, p. 271.

SECTION B.

2. Cf. Bone, Newitt, and Townend in *Proc. Roy. Soc.*, A, **103**, p. 205 (1923); *ibid.*, **105**, p. 406 (1924).

4. Expected to be offered for publication in *Trans. Chem. Soc.*; for other references cf. *J.C.S. Trans.*, 1921.

5. Expected to be published in *Journ. Soc. Chem. Ind.*

6. To be published in *Canadian Chemistry and Metallurgy*, and in *Industrial and Engineering Chemistry* (U.S.A.).

13*d*. Cf. Bone, Cantor lectures pubd. in *Journ. Roy. Soc. Arts*, 1922; *id.*, *Proc. Roy. Soc.*, A, **99**, p. 236 (1921).

14*a*. To be published in *Canadian Chemistry and Metallurgy*; cf. *ibid.*, **8**, no. 8, p. 194; no. 9, p. 208 (1924).

14*h*. Kenrick, Gilbert, and Wismer, 'Superheating of Liquids,' and Kenrick, Wismer, and Wyatt, 'Supersaturation of Gases in Liquids,' in *Journ. Phys. Chem.*, Nov. 1924.

SECTION C.

1*b*. Cf. *Annual Reports*, Ontario Dept. of Mines.

4. Cf. 'Some features of the Kansan drift of southern Iowa,' in *Geol. Soc. Amer. Bulletin*, **27**, pp. 115-17 (1916); 'Gumbotil, a new term in Pleistocene geology,' in *Science*, n.s., **44**, pp. 637-8 (Nov. 3, 1916); 'Pleistocene deposits between Manilla in Crawford county and Coon Rapids in Carroll county,' *Iowa Geol. Surv.*, **26**, pp. 215-231; also abstract *Iowa Acad. Sci. Proc.*, **24**, pp. 99-100 (1917); also *Bull. Geol. Soc. Amer.*, **29**, 18; 'The Origin of Gumbotil' (with J. N. Pearce), in *Jour. Geol.*, **28**, no. 2, pp. 89-125 (Feb.-Mar. 1920); 'Significance of the relation of Proboscidean remains to the surface of Nebraskan Gumbotil, near Osceola, Clarke county, Iowa,' in *Bull. Geol. Soc. Am.*, **32**, pp. 81-83 (1921); 'A comparative study of the Nebraskan and Kansan tills in Iowa,' *ibid.*, **33**, p. 115 (Mar. 1922); 'Recent studies of the Pleistocene in western Iowa,' *ibid.*, **35**, pp. 71-73; 'A new interpretation of the type sections of Aftonian gravels in Iowa,' in *Journ. Geol.* (in press).

5. Cf. 'Dinosaurs of Alberta,' in local *Handbook* for meeting; 'Dyoplosaurus acutosquameus and Notes on Prosaurolophus Maximus,' *Univ. of Toronto Studies* (in press, Sept. 1924).

6. Cf. paper on 'Cothurnocystis,' to appear in *Palæontologische Z.*, 1925.

11. *Univ. of Toronto Studies*, Geol. Series, 17. Cf. 'South Lorrain Silver District, Ont.,' *Trans. Amer. Inst. Mining and Met. Eng.*, Jan. 1924; 'Deep-seated oxidation

and secondary enrichment at Keeley Silver Mine,' *Econ. Geol.*, **18**, vii (1923) ; 'Occurrence of silver ores in South Lorrain, Ontario, Canada,' *Bull. Inst. Mining and Metal.*, Feb. 1922.

12. *Mineralog. Mag.*, **20** (1925).

21*b* (*e*). Subject expected to be published in *Amer. Journ. Sci.* and *Bull. Geol. Soc. Amer.* Cf. *Journ. Geol.*, 32, no. 4, May-June, 1924.

21*b* (*g*). To be published in *Econ. Geol.*

25. To be published in *Journ. Geol.* (Chicago).

26. To be presented to Geol. Soc., London.

Section D.

5. Expected to be published in *Journ. Genetics* or *Brit. Journ. Exper. Biol.* Cf. *Brit. Journ. Exper. Biol.*, **1**, i (1923).

6. Cf. *Proc. Roy. Soc.*, B, **95** (1923) ; *Brit. Journ. Obstet. and Gynæcol.*, Oct. 1924.

9. Expected to be published in *Brit. Journ. Exper. Biol.*

11. Probably to be published in *Bull. Entom. Research.* Cf. 'Some Blood-sucking Flies of Saskatchewan,' in *Agric. Gaz. Canada*, **5**, no. 6 (1918).

16. To be published in fuller detail in *Journ. Comparative Neurology.* Cf. 'On the Relative Vascularity of Various Parts of the Central Nervous System of the Albino Rat,' in *Journ. Comp. Neur.*, **31**, pp. 429-464 (1920) ; 'The Vascularity of the Cerebral Cortex of the Albino Rat,' *ibid.*, **33**, pp. 193-212 (1921).

22. Cf. *Univ. of Toronto Studies* ; papers of *Ont. Fisheries Research Lab.*

23. Cf. 'Rate of growth and food of the lake sturgeon,' *Pubns. of Ontario Fisheries Research Lab.*, **17-21** (Biol. Series, Univ. of Toronto).

31. Intended to be presented to *Proc. Zool. Soc., London.*

Section E.

1. To be published in *Scot. Geog. Mag.*

3. Leaflet and publications of Permanent Committee on Geographical Names, Roy. Geog. Soc., London.

8. Cf. 'Magnetic observations in Western Canada,' Topog. Surv. of Canada *Bull.*, **46** ; 'Magnetic results in Western Canada,' *ibid.*, **52** ; 'Diurnal inequality of Declination at Aklavik, N.W.T.,' *Journ. Roy. Astron. Soc. Canada* (June-July, 1924), and other articles, *ibid.*

10. Cf. *Trans. Roy. Soc. Canada*, **4**, iii, N.S., 1910.

14. Cf. 'The Rôle of the Glacial Anticyclone in the Air Circulation of the Globe,' in *Proc. Am. Phil. Soc.*, **54**, Aug. 1918, pp. 185-225 ; 'The Fixed Glacial Anticyclone compared to the Migrating Anticyclone,' *ibid.*, **60**, 1921, pp. 34-42 ; 'The Mechanics of the Glacial Anticyclone illustrated by Experiment,' *Nature*, July 22, 1920.

18. To be published in *Scot. Geog. Mag.* Cf. 'The Ituri Forest, River, and Pygmies,' in *Geog. Journ.*, **46**, no. 3 (1915) ; 'The Bahr el-Ghazal and its Waterways,' *ibid.*, **61**, no. 5 (May 1923) ; *Big Game and Pygmies* (Macmillan, 1924).

19. To be published in *Amer. Geog. Review.*

20. To be published in *Scot. Geog. Mag.*

23. Cf. 'Subdivision of N. America into Natural Regions : a preliminary enquiry,' *Ann. Assoc. Amer. Geographers*, **4**, pp. 55-83 (1914).

Section F.

2*b*. To be published in *Metron* (Ferrara, Italy).

3. See Presidential Address to *Roy. Statist. Soc.*, Nov. 1924, to be published in Society's *Journ.*

6. To be published more fully in *Journ. Pol. Econ.* Cf. 'The Progress of Economics,' in *Q.J. Econ.*, **26**, pp. 1-67.

7. *Financial News*, Aug. 25, 26 (1924).

8*a*. *Nature*, Nov. 8, 1924.

10*b*. Expected to be published in *Brit. Econ. Journ.*, Mar. 1925. Cf. papers privately printed by author: 'Chicago Wheat Prices for Eighty-one Years'; 'Wheat Prices and Wheat Receipts in Chicago—Their Correlation for Ten Crop Years, July 1, 1904, to June 30, 1914'; 'Cost of Marketing Grain'; 'The Law of Supply and Demand and the Wheat Market'; 'The Chicago Board of Trade—What it is and what it does.'

SECTION G.

2. *Engineering*, Aug. 22, p. 266.

3. *Engineering*, Aug. 22, p. 266.

4. *Engineering*, Aug. 29, p. 301. *Canadian Engineer*, Aug. 19, 1924; Aug. 29, p. 301; cf. paper at World Power Conference, London, July 1924.

5. *Engineering*, Aug. 15, p. 193; Aug. 22, p. 255.

6. *Engineering*, Aug. 15, p. 239; Aug. 22, p. 271; *Canadian Engineer*, Aug. 19, p. 26, 1924; reprint from latter obtainable from author, 340 University Street, Montreal,

7. For Mr. Kimball's contribution, cf. 'Stress in Railway Motor Pinions,' in *Trans. Amer. Soc. Mechan. Eng.*, 1922; *Gen. Elec. Rev.*, Feb. 1924; 'Stress Determination by means of the Coker Photoelastic Method,' in *Gen. Elec. Rev.*, Jan. 1921; P. Heymans and Kimball, 'Stress Distribution in Electric Railway Motor Pinions as determined by the Photoelastic Method,' *ibid.*, Mar. 1923.

8. *Engineering*, Aug. 29, p. 284.

9. *Engineering*, Aug. 15, p. 245.

10. *Engineering*, Aug. 29, p. 284; Oct. 1924.

11. *Engineering*, Aug. 29, p. 286.

12. *Engineering*, Aug. 29, p. 284.

13. *Engineering*, Sept. 15, p. 343.

14. *Engineering*, Aug. 29, p. 286.

16. *Engineering*, Aug. 29, p. 286.

17. *Engineering*, Aug. 15, p. 241.

18. *Engineering*, Aug. 22, p. 274; Aug. 29, p. 302; cf. 'Permanent Magnets, and the relation of their properties to the constitution of Magnet Steels,' in *Journ. Inst. Elec. Eng.*, **61**, no. 319.

19. *Engineering*, Aug. 29, p. 287.

20. *Engineering*, Aug. 22, p. 257.

SECTION H.

1. See Haddon, *The Races of Man and their Distribution*, Cambridge Univ. Press, 1924 (pp. 139-157).

2. *Proc. Roy. Soc. Canada*, 1921-22, and Presidential Address to Section II., *ibid.*, 1923.

6. Cf. *Year's Work in Classical Studies*, 1922-3, pp. 97-116; *The Times Lit. Supp.*, Jan. 10, 17, 1924.

7. Cf. *Papers of Brit. School at Rome*, **1** (pp. 125-285), **3** (1-212), **4** (1-159), **5** (213-432), **8** (104-171), with Mr. R. Gardner; *Journ. Roman Studies*, **11**, pp. 125-190 (1921), with Mr. R. A. L. Fell.

10. To be published in *American Anthropologist*.

11. *Classical Philology* (Univ. of Chicago Press), Jan. 1925.

16. Cf. *Proc. Ninth Internat. Congress of Americanists*, Wash., 1917; revised in current *Annual Rep. of Smithsonian Inst.*

21. To be published in *Journ. Phys. Anthrop.*, Washington.

23. To be ublished in *Man*.

28. Material to be included in report to Anthrop. Div., Dept. of Mines, Ottawa, and expected to be published in *Anthropol. Series*, Victoria Memorial Museum, Ottawa.

30. To be published in *Bull. Amer. Mus. Nat. Hist.*, 1925. Cf. *ibid.*, **35**, art. xix, especially pp. 254-257, 277-279, 293-295, 295-298, 305-309, 341-344; Williams and Wilkins, *The Origin and Evolution of the Human Dentition*, Baltimore, especially pp. 324, 379, 381, 409, 419, 426, 429, 481.

32. Substance to be published in *Amer. Anthropologist; Indian Notes and Monographs* of Heye Museum, N.Y.; *Proc. Congress of Americanists*, The Hague.

33. Cf. *Indian Notes*, Heye Museum, N.Y., **1**, ii, pp. 76-83, Apr. 1924; full report on Santa Barbara skeletal remains to be published, *ibid.*

39. *Man*, Nov. 1924.

SECTION I.

3. Preliminary notice in *Proc. Nat. Acad. Sci.*, **10**, vi, p. 245 (1924); complete paper to be published in *Amer. Journ. Physiol.*

4. Cf. *Amer. Journ. Physiol.*, **69**, pp. 605-633 (1924); *Physiol. Rev.*, **4**, pp. 163-190 (1924).

6. Preliminary notice in *Report* Internat. Physiol. Congress, Edinburgh, by Dr. Jane Sands, *Q.J. Exper. Physiol.*, Supp., 1923, p. 215. Further part of work in *Amer. Journ. Physiol.*, Nov. 1924.

7. To be published in *Journ. Exper. Med.*, *Amer. Journ. Physiol.*, or *Archives of Internal Medicine.*

8. Sent for publication to *Q.J. Exper. Physiol.* Cf. Ivy and Whitlow in *Amer. Journ. Physiol.*, **60**, p. 578 (1922): Ivy and Malvain, *ibid.*, **67**, p. 124 (1923).

9. *Amer. Journ. Physiol.*, Nov. 1924.

14. *Amer. Journ. Physiol.*, **69**, pp. 337-353 (1924).

15. Cf. 'Effect of Respiration on the Venous Pulse as studied by the Electropolygraph, to be published in *Amer. Journ. Physiol.*; Waud, 'An Electric Polygraph,' in *Journ. Amer. Med. Assoc.*, **82**, p. 1263 (1924); F. R. Miller and Waud, 'Further Studies with the Electropolygraph,' in *Trans. Roy. Soc. Canada*, Sec. V., p. 155 (1924).

18. Cf. 'Microdissection Studies III. The Cell Aster; a reversible gelation phenomenon,' in *Journ. Exp. Zool.*, **33**, pp. 483-504 (1917); 'Changes in Protoplasmic Consistency and their relation to cell-division,' in *Journ. Gen. Physiol.*, **11**, pp. 49-68 (1919); 'The Physical Structure of Protoplasm as determined by microdissection and injection,' in *General Cytology*, Section V., pp. 237-309, Univ. Chicago Press, 1924. Further work expected to be published in *Brit. Journ. Exper. Biol.*

20. To be published in *Journ. Pharmacol. and Exper. Therapeutics.*

21. To be published in *Journ. Amer. Chem. Soc.*

24. *Journ. Biol. Chem.*, **62**, p. 15.

25. Cf. series on 'Studies of Gas and Electrolyte Equilibria in Blood,' *Journ. Biol. Chemistry* for 1922.

26. Cf. Shaffer and Friedemann, *Journ. Biol. Chem.*, **61**, Oct. 1924; *ibid.*, **47**, pp. 433, 449 (1921); **54**, p. 399 (1922).

27. To be published in *Journ. Biol. Chem.* Cf. E. C. Gray and E. G. Young, 'The Enzymes of B. coli communis,' in *Proc. Roy. Soc.*, B, **92**, p. 135 (1921).

30. Cf. J. H. Bevan and H. P. Marks in *Journ. Physiol.*, **59**; *Proc. Phys. Soc.*, May 24, 1924.

31. To be published in *Amer. Journ. Physiol.* Cf. *ibid.*, **68**, p. 542; **69**, p. 548 (1924).

35. Offered for publication to *Journ. General Physiol.*

36. To be published in *Q.J. Exper. Physiol.*

37. Cf Miller and Simpson in *Trans. Roy. Soc. Canada*, V., **18**, 1924; further material probably in *Amer. Journ. Physiol*

SECTION J.

1. To be published in *Brit. Journ. Psychol.*; cf. *Remembering and Forgetting* (esp. ch. iv, vi, xii), Methuen; *Skill in Work and Play*, Methuen; 'Imagery and Mentality,' *Brit. Journ. Psychol.*; 'Vehicles and Routes of Thought,' *Discovery*; 'Is thinking the action of language mechanisms?' *Brit. Journ. Psychol.*; 'Mental Tests and Mentality,' *Psyche*.

2. To be published in *Journ. Abnormal Psychol. and Social Psychol.* Cf. 'Theories of temperament, an attempt at reconciliation,' *Psychol. Review*, **30**, i, Jan. 1923.

3. To be published in *Brit. Journ. Psychol.* (general section).

9*c*. *Psychol. Review* (U.S.A.), Jan. 1925.

16. Cf. Spearman, *The Nature of Intelligence and the Principles of Cognition*, 1923.

17. See McCurdy, *The Psychology of Emotions.* (Kegan Paul, in press).

SECTION K.

1*a*. Cf. *The Transpiration Stream*, to be published by London University Press; also Presidential Address to Section K, B.A. *Report*, Hull, 1922.

1*c*. Cf. *Carnegie Inst. Wash.*, public. no. 350, and further pub. expected Apr.-May, 1925.

4. Cf. *Ann. Bot.*, **38**, pp. 563-595, and **39** (1924).

5. To be published in *Trans. Roy. Canadian Inst.* Cf. 'The fluorescent colors of plants,' *Science*, **59**, pp. 241-248, March 14, 1924; 'The fluorescence of certain lower plants,' *Nature*, **112**, pp. 132-133, July 28, 1923; 'A method of ultramicroscopy whereby fluorescence in the Cyanophyceæ and Diatomaceæ may be demonstrated,' *Science*, **58**, pp. 91-92, Aug. 3, 1923; 'Ultramicroscopically observable fluorescence,' *Science*, **58**, pp. 229-230, Sept. 21, 1923; 'Fluorescence in the Cyanophyceæ,' *Trans Roy. Soc. Canada*, **17**, pp. 129-136, 1923.

9. *Trans. Roy. Soc. Canada*, 1924.

10. Cf. *Studies in Soil Acidity: the importance of the Light Factor*, Camb. Univ. Press, 1923.

15. To be published in *Annals of Botany*.

18*a*. *Journ. Forestry* (Soc. Amer. Foresters), Dec. 1924.

22. *Trans. Roy. Soc. Canada*, V., **18**, 1924.

23. To be published in *Amer. Naturalist*.

23*a*. To be published in *Nature*; cf. 'Polyploidy,' *Brit. Journ. Exper. Biol.*, **1**, pp. 153-182 (1924).

23*e*. Cf. Blackburn and Heslop Harrison, 'Status of the British Rose Forms as determined by their Cytological Behaviour,' in *Ann. Bot.*, **35** (1921); 'Genetic and Cytological Studies in Hybrid Roses, I.,' in *Brit. Journ. Exper Biol.*, **1** (1924).

25*b*. Greater part in *Canadian Forest and Outdoors Mag.*, Oct. 1924: remainder to be published, *ibid.*

27. Cf. 'Vegetation of the North Coast of Greenland . . .' in *Medd om Grönland*, **64**, pp. 221-268 (Copenhagen, 1923).

SECTION L.

1. To be published in *Canadian Histor. Rev.*

14. *The School* (Toronto), Nov. 1924.

SECTION M.

2. To be published in *Journ. Agric. Sci.*

3. To be published in *Journ. Agric. Sci.*

4. Mr. Cameron's communication expected to be published in *Ann. Applied Bot.* Cf. 'General Survey of the Insect Fauna of the Soil,' in *Journ. Econ. Biol.*, **8**, no. 3 (1913); 'Insect Association of a Local Environmental Complex,' in *Trans. Roy. Soc. Edin.*, **53**, pt. 1, no. 2 (1917); 'Relation of Soil Insects to Climatic Conditions,' in *Agric. Gaz. Canada*, **4**, no. 8 (1917).

12. Cf. 'Influence of Rainfall upon yield of Wheat at Rothamsted,' in *Phil. Trans.* B, **213**, pp. 89-142.

14. To be published in *Journ. Agric. Sci.*

OFFICIAL JOURNEYS.

I.—Quebec, Montreal, and Ottawa.

The total number of members travelling from the British Isles to attend the Toronto Meeting was 577. Of these 235 sailed from Liverpool on the Cunard R.M.S. *Caronia* on July 26, and of the rest smaller numbers sailed on the Canadian Pacific vessels *Montrose*, *Montlaurier*, and *Melita*, and the White Star vessel *Megantic*. Members on ships which proceeded to Montreal had the option of leaving them at Quebec and travelling to Montreal by train without additional charge.

As there were at least four clear days between arrival in Canada by the above ships and the opening of the Meeting in Toronto, arrangements were made for members who so desired to view Quebec, Montreal and Ottawa. A large body availed themselves of this opportunity, which was afforded through the generous co-operation of Government and University authorities with the local executive committee in Toronto, while the detailed arrangements were admirably carried out by Col. H. T. Bovey, of McGill University, Montreal, acting under the direction of Gen. Sir Arthur Currie, president of the University.

At Quebec on Saturday, August 2, members used the Jacques Cartier room at the Château Frontenac Hotel as a reception room, visited the Citadel and other points of historical interest in the city, and were entertained to tea at Spencerwood, the residence of the Lieutenant-Governor, Sir Louis P. Brodeur. The majority of the party proceeded the same evening to Montreal by special train on the Canadian National Railway, stopping *en route* for an inspection of the great bridge over the River St. Lawrence, above Quebec, and sleeping on the train.

At Montreal on Sunday and Monday, August 3 and 4, a reception room was opened in the Mount Royal Hotel. On Sunday the members were entertained to tea by Lord Atholstan. On Monday McGill University, Macdonald College (where luncheon was provided), and other educational institutions were visited; some members inspected the harbour (as guests of the Harbour Commission) and the St. Lawrence power plants, and carried out a botanical excursion in the vicinity of the city. On Monday night the majority proceeded by special C.N.R. train to Ottawa; Tuesday morning, August 5, was spent in viewing the city. They were entertained to lunch by the Dominion Government, the Premier, Mr. McKenzie King, and many members of the Cabinet being present. The Premier welcomed the Association party and spoke at length on the many advantages of scientific research. The President (Sir Ernest Rutherford) replied. In the afternoon the train left for Toronto, which was reached at 9 p.m.

II.—The Transcontinental Excursion.[1]

The Transcontinental or Western Excursion after the Meeting, from Toronto to Vancouver and Victoria, B.C., and back, was taken by about

[1] Thanks are due to Mr. W. H. Barker, who collected the notes from which this narrative is largely compiled, and to the following members who contributed them: Mr. H. Balfour, Mr. J. Bartholomew, Mrs. Bisbee, Prof. W. J. Dakin, Miss A. J. Davey, Dr. Gertrude Elles, Prof. W. T. Gordon, Prof. H. M. Hallsworth, Mr. H. T. Harris, Prof. J. W. McBain, Dr. Marion Newbigin, Prof. J. H. Priestley, Dr. A. B. Rendle, Miss Ridgeway, Mr. O. H. T. Rishbeth, Dr. G. Scott Robertson, Dr. F. C. Shrubsall, Prof. W. W. Watts.

360 persons, including 27 members of the International Mathematical Congress, which had been held in Toronto from August 12 to August 16. The members travelled in two special trains provided by the Canadian National Railway (Train A) and the Canadian Pacific Railway (Train B) respectively. Each train consisted of a baggage-car, car for the train staff, two dining-cars, eight standard sleeping-cars, and one observation car with sleeping compartments. The total length of each train was about 370 yards; this was increased, on the mountain section of the Canadian Pacific route, by the addition (kindly made by the railway company to both trains) of an open observation car. The trains travelled on the outward journey to Vancouver over the lines of the Canadian National Railway (excepting the section from North Bay to Cochrane—Timiskaming and Northern Ontario Railway); the return journey was made over the Canadian Pacific line. The rate for the journey to Vancouver and back, including sleeping accommodation, was fixed at $100, and table d'hôte breakfast, luncheon and dinner were provided in the dining-cars at a total charge of $3 per day. The local committee in Toronto generously invited some of the members to make the journey as their guests, with a remission or reduction of the travel rate. Contributions toward the cost of the excursion were made by some of the provincial governments, and the most generous hospitality was enjoyed at every point, at the hands alike of public bodies and private individuals. The excursion was acknowledged by all who were privileged to take part in it as an unqualified success and a wonderful experience, and among all those who laboured to make it so the gratitude of the participants is especially due to Mr. D. B. Hanna, to whom, as chairman of the Finance and Transportation Committee in Toronto, fell the major part of the preliminary arrangements with the railway companies; to Dr. Willet G. Miller and Dean R. W. Brock (of the University of British Columbia), who shared the planning of the excursion and the conduct of the party; to Sir Robert Falconer, President of the University of Toronto, who also generously sacrificed his time to join the excursion, and to Prof. W. A. Parks, who represented the local executive on Train B. The staffs of the two trains were admirably efficient.

Sunday, August 17.—The trains, carrying the excursion party with the exception of the botanists and geologists referred to below, left the Union Station, TORONTO (254 ft.),[2] in the evening.

Monday, August 18.—At TIMAGAMI (309 m., 986 ft.)[2] a botanical party of some 25 members, who had left Toronto on August 14, joined the main body.

This party had reached Timagami in the morning of August 15, and were conveyed by steamer on the lake to Bear Island, the members being distributed for purposes of sleeping accommodation between Turner's Camp, Prof. Faull's laboratory on Bear Island, and Smith's Camp on Garden Island.

In the afternoon of August 14 a motor-launch conveyed the party to Timagami Island (north end), a trail being then followed for about four miles through virgin forest to the Wabikon Camp at the south of the Island. Chief Ranger Hyndson conducted the party. Interesting examples of old trees of both red and white pine were seen *en route*, as well as very characteristic undergrowth and fine examples of regeneration by deciduous trees after the coniferous forest had been destroyed by fire.

[2] Distances of principal points are given in miles (m.) from the start of the excursion at Toronto throughout; elevations in feet above sea-level.

On Saturday, August 16, Sandy Inlet, to the north of Bear Island, was visited by motor-launch, where a number of interesting plants were seen, including marsh and aquatic plants in and near the Edye River, and a ground flora under a nearly pure stand of Banksian Pine to the north-west of the Inlet. In the evening many members of the party derived considerable pleasure from watching, and in some cases sharing in, a dance at Smith's Camp, in which the native Indians were prominent in square dances.

On Sunday, August 17, in the morning, the trail to the Fire Observation Post on Bear Island was thoroughly examined for plants, and some of the experimental cultures of rust fungi on spruce under field conditions, carried out by Prof. Faull and Mr. Watson, were also seen. In the afternoon the party proceeded by launch to Cochrane Island, and then by canoes propelled by boys from Mr. Cochrane's camp to the mainland, where a portage trail was followed to another inlet of the lake. The expedition throughout was exceedingly successful.

At COBALT (330 m., 969 ft.) a short stay permitted the town and district to be visited. The larger party inspected the Nipissing and the Cobalt Reduction Company's Mining Mills. Of recent years the output of silver has considerably decreased. Formerly some thirty mills employed over 4000 men. There are now approximately only ten mills, with little more than 1000 employees. New mines in the neighbourhood have absorbed a few hundreds of the unemployed. The arrangements made, whereby the party was conducted over the works in small groups, enabled the whole processes from crushing to refining the silver to be seen. In 1904, the year in which the first shipments were made, Cobalt produced 159 tons of ore carrying 5·34 per cent., or 1309 ounces, of silver per ton, and from 1904 to the end of 1923 about 343,895,780 ounces of silver, valued at $227,700,000. (For further details of the Cobalt area, see below, under date of August 19.)

An agricultural party was taken by motor-cars through some twelve miles of cultivated country, and rejoined the train at Liskeard, after visiting the Dominion Experimental Farm and Mr. A. J. Kennedy's Glengarry Stock Farm.

Both places are situated about four miles from New Liskeard on the South Clay Belt. The soil consists of alternate layers of light and dark medium loam. The light-coloured layers contain chalk and the darker layers have a high organic matter content. In spite of the high elevation and northern situation, agricultural efforts are meeting with considerable success. The long summer days make feasible the ripening of cereal crops within ninety days of sowing. The Government Experimental Farm is devoting special attention to investigation (*a*) as to types of crops which can be successfully grown, (*b*) suitable varieties of different crops—dates and rates of sowing and ripening, (*c*) the grading of stock for distribution to farmers.

Hay is the chief crop, but, owing to the supply being greater than the demand in recent years, a large proportion of the farmers are turning their attention to mixed farming. The usual rotation is :

(1) Oats, barley or wheat ; (2) hay ; (3) hay ; (4) hoe-crop maize, sunflower for silage, potatoes, turnips, etc. The crops are sown during the last fortnight of May and the harvesting of the cereal crop begins in the last days of August. No artificial fertilisers are used. Stock-keeping is developing, particularly dairy stock of the Shorthorn and Friesian breeds. On Mr. Kennedy's farm, for example, there is a herd of 23 pure-bred Friesian cows from which milk is supplied to a creamery at New Liskeard, whence it is distributed as milk or butter in the mining towns of the neighbourhood. The development of stock is greatly needed in the Southern Clay Belt.

The experiments at the Experimental Farm have shown that flax-seed can be grown satisfactorily, and there are prospects for the development of a flax-fibre industry. There is an increasing demand from Southern Ontario for seed potatoes from this district.

Some idea of the development which has taken place may be gathered from the

fact that 25 years ago the 300,000 acres of the Southern Clay Belt were sold to settlers in blocks of 160 acres at the price of 50 cents per acre.

The value of the farms to-day varies from $30 to $40 per acre. As high a price as $120 per acre has been obtained for certain farms during the immediate post-war years.

Passing through the Clay Belt from Haileybury (north of Cobalt), there could be seen from the trains the scattered homesteads of settlers taking advantage of the clearing of the forest by the devastating fires of recent years to bring the Clay Belt under cultivation. The contrast between the Clay Belt and the 'wilderness' area beyond its limits is remarkable. Over the cleared areas only aspen bushes remain to mark the site of the original forest, but at Engelhart station *Acer negundo* and larch have been planted as ornamental trees. The level surface, the absence of bare rock, and the luxuriant growth of grasses and other herbs mark the contrast between this Clay Belt and the undulating areas where the Archæan rocks outcrop, with alternation of swamps and rounded, ice-smoothed rock surfaces.

The peculiar form and origin of Lake Timiskaming, an expansion of the Ottawa River sixty-seven miles long and five miles in maximum width, gave rise to discussion among the geographers in finding a generic name for a similar sequence of processes elsewhere; it was suggested that the name of the lake might be so applied, as for example (especially in American usage) the name of Monadnock has come to be employed to signify a particular type of mountain-structure.

At SWASTIKA (392 m., 1006 ft.) the trains left the main railway track and proceeded along a new line to the mining centre of KIRKLAND LAKE. These were the first passenger-trains to pass over the line; in fact, the line was still under construction and the last spike of that section was driven as the first train came in sight. Guides conducted groups round the various mining buildings. There are several mines at Kirkland Lake; the larger number of the party saw all the processes for extracting gold from the ore at the Wright-Hargreaves Mills. The ore treated in this district is reddish in colour, owing to the large amount of red porphyry which has been intruded among the other rocks. The ore was seen as it came from the mine, and the processes of crushing, cyaniding for extracting the gold from the slimed ore, treatment of the solution with zinc, and precipitation and recovery of the gold were witnessed.

The assaying department was of special interest to some of the members.

After the party had inspected the mills, many went to the village, which gives an excellent idea of a mining community in its early stages; this gold-field was discovered in 1912. Others went to the Lake Shore Mine. In this mine at present the deepest shaft is 1000 feet; a small party was taken down, choosing to go to the 600-foot level, as more of the working could be seen there than in the lower levels.

At Swastika some members of Section H (Anthropology) visited an English family who had emigrated from London some eighteen months previously. They had come from a one-roomed tenement, where they had suffered much in health and the husband had long periods of unemployment. In the brief period they had been in Canada circumstances had changed. The man was earning $100 per month, the wife was acting as a maternity nurse, earning $30 per case, and the children earn a little by picking berries. They occupied a frame-house with three rooms, a kitchen, electric light, and a small garden plot. The children were now in good health and doing well at school, and none had a desire to return to London.

Tuesday, August 19.—TIMMINS (485 m., 1029 ft.), in the Porcupine gold area, was reached in the morning, and a visit was paid to the Hollinger Gold Mines. A short walk from the train across what was once an arm of Porcupine Lake brought the party to their first objective, the power station. In Porcupine Lake, as in other waters in the vicinity of mines, the natural processes of silting are being hastened by the injection of waste sediments (sludge) from the mines. Large clayey or sandy tracts result, and at Timmins it is proposed to use these as building sites or for recreation grounds. At the power station the party, guided by the engineer in charge, inspected the fine installation (duplicate throughout) of modern power-generating plant. From the power station the party proceeded to the mills and workshops. Dividing here into small sections, each under a competent guide, they were shown on the one hand the complicated processes of extraction from the rough-crushed ore, and on the other the very complete repair and accessory outfitting plant which makes this mine, in its somewhat remote location, practically self-supporting in this direction. From the mill the members proceeded to a shaft, which some of them descended to the 1100-foot level. Here they were shown the main galleries—excellently cut, dry, and furnished with electric lighting and an electric traction system. The nature of the ore lodes was explained to them and an insight was gained into the actual methods of drilling, blasting, 'mucking' (shifting of rough-broken ore), ore-crushing and ore-transport.

The main excursion was joined at Timmins by a geological party of thirty members who had left Toronto on August 14. They travelled as guests of the Ontario Government, in charge of Dr. W. G. Miller, of the Ontario Department of Mines. At Timagami, the first halt, on August 15, he demonstrated several points of interest in close proximity to that station. The Cobalt series, of Pre-Cambrian age, exposed here, ranged from coarse conglomerates to fine-grained greywacké, but the metamorphism was not of an intense character. A few hundred yards north of the station a conglomerate bed of the Cobalt series rests unconformably on the Keewatin rocks, and has been considered a tillite, but the evidence that these conglomerates are of glacial origin was not conclusive in the sections examined. Crossing the railway track, the Keewatin rocks were next examined, and among them members of the iron (jaspilite) series showed up on pavements smoothed by the Pleistocene glaciation. Rejoining the train, the party proceeded to Cobalt, and on arrival was transported by car to the Keeley Mine, South Lorrain. Dr. Mackintosh Bell had organised this visit so that the more important features might be seen in the minimum of time. The great variety of minerals in this mine, in addition to silver, was indicated by the number of cobalt and nickel arsenides, sulph-arsenides and their oxidation products, which could be collected on the ore-dumps. The veins of native silver were, of course, the most spectacular features. Such veins were seen on more than one level in the mine. On a neighbouring property—the Mining Corporation of Canada (Frontier Mine)—a fine series of specimens was laid out for inspection. The mineralisation is connected with the intrusion of the Nipissing diabase and the greater part of the ore comes from the Keewatin-diabase contact zone. The party was entertained to dinner by the Keeley Mine Company and the Mining Corporation, The return to Cobalt was made after dark, so that examination of the Cobalt area was held over until August 16. Mr. C. W. Knight, of the Nipissing Mines Ltd., conducted the party on Saturday and demonstrated in the first instance the Cobalt series resting on the Keewatin pillow-lavas. The oldest bed of the series was a well-marked breccia 2-3 ft. thick and overlain by conglomerates. The latter were easily examined on the glaciated surfaces exposed in the search for veins during exploration work on the area, and the size and variety of boulder was a distinctive feature of the beds. Finer-grained beds (greywacké) also were present, but, even in these, boulders were of common occurrence. The Nipissing diabase intrusion was in contact with the greywacké at this place, and, as one would expect, it was very fine-grained nea

the margin and coarser towards the interior of the mass. Proceeding to the Little Silver Mine (where one of the original discoveries was made) members saw the greywacké and overlying Cobalt quartzite exposed. A visit to the smelting and refining plant of the Mining Corporation concluded the tour, and, leaving Cobalt in the late afternoon, Swastika was reached at sunset.

On August 17 an early start was made, and cars conveyed the party to Kirkland Lake, where Mr. J. B. Tyrrell met and entertained the company to breakfast. Mr. A. G. Burrows, of the Ontario Department of Mines, then explained the geology of the area, where syenite, porphyry, and lamprophyre intruding into the Timiskaming conglomerates had deposited gold-ore in veins. At the Lake Shore Mine specimens with visible gold were laid out for examination, and at the Tough-Oakes-Burnside Mine both gold and gold-tellurides were collected by the party on the ore-dumps. The extraction plant of the Wright-Hargreaves Mine was examined about midday. On the return to Swastika the car was joined on to the train for Timmins.

Early on Monday, August 18, Mr. Burrows assembled the party for the excursion to the Porcupine area. Leaving the train at Dome Mine Station, the Timiskaming beds between this and the mine were carefully examined. The beds here were tilted at a fairly high angle and had suffered some metamorphism, though again not of an intense character. These strata had been injected by quartz porphyry, which had in the vicinity of the mine kept fairly close to the Keewatin-Timiskaming junction. The gold-bearing solutions had been accompanied by siliceous solutions, and the principal ore production is from the quartz veins associated with the Timiskaming sediments as distinct from the conditions at the Hollinger Mine, where veins in the Keewatin greenstones yield the bulk of the ore. It is true, however, that there is some gold production from the Keewatin junction at the Dome. After lunch at the Dome Mine the afternoon was spent examining the pillow-lavas of the Keewatin series, but near the Dome the junction of the Timiskaming with the Keewatin was pointed out. The party split up at the Paymaster Mine, some returning to Timmins *via* the Vipond Mine and others *via* the Hollinger or the McIntyre.

Early next morning the general party arrived at Timmins. Mr. Burrows again led a small party to see some of the rocks round the Hollinger Mine. Intrusions of quartz porphyry into the Keewatin lavas were again noted, and one remarkable example of pipe intrusion gave a wonderful idea of the gradation between bulk injection and lit-par-lit injection as seen in other areas. The mine itself was now entered and the general process of gold-extraction followed from start to finish.

From Timmins the excursion proceeded to Iroquois Falls (492 m., 905 ft.), where the works of the Abitibi Power and Paper Company are situated—modern pulp and paper mills, producing almost entirely news-print, which the members thoroughly inspected in small parties under the guides detailed by the Company. Power is derived from the Iroquois and Twin Falls on the Abitibi River. The town is built on ground leased to the Company for ninety-nine years and is laid out on the lines of a garden city (contrasting strongly with the mining towns visited). In addition to houses, the Company provides a hostel for employees who cannot be otherwise accommodated: this serves also as an hotel. While the Company is the overlord, local affairs are largely in the hands of an elected municipal council, which levies rates and manages the school, public gardens, athletic grounds, etc. The stores, laundry, tea-rooms, and various other institutions are to some extent under the supervision of the Company.

The trains reached the main transcontinental line of the Canadian National System at Cochrane, and turned west along it, leaving Northern Ontario and entering Manitoba near White (1201 m.).

Wednesday, August 20.—Winnipeg, the capital of Manitoba (1294 m., 772 ft.), was reached in the evening, and the party was met by members of the local committee. Here many acquaintances dating from the meeting of the Association in the city in 1909 were pleasantly renewed.

Members were received in the Parliament Building by the Hon. John Bracken, Premier, and other representatives of the Provincial Government.

Thursday, August 21.—Through the kindness of the Union Bank officials, members obtained an excellent view of the city from the high elevation of the Bank Buildings. From the small beginnings of Fort Garry at the junction of the Red and Assiniboine rivers has developed the modern city of enormous dimensions in a vast plain of extensive horizons. The two great railways, the wholesale stores of towering height, and the mills afforded some illustration of Winnipeg's claim to be the gateway of the West. In such capacity it has become the great outlet of the grain from the prairies. In a real sense the Grain Exchange is the centre of Winnipeg's activities.

Members had an opportunity of inspecting the Exchange. The wheat pit or ring is immediately within the entrance, and has on one edge a pulpit, opposite to which is a platform, above which the prices of wheat at other great exchanges of North America, such as Chicago, Minneapolis, and Duluth, are exhibited as received by telegraph to those buying and selling in the pit: similarly, messages are sent from the pulpit to other centres, giving Winnipeg prices. Adjacent to the wheat pit is another for dealings in oats, corn, etc. Elsewhere in the room maps of North America and the North-West of Canada are exhibited for the purpose of showing weather conditions. Off the main room are situated the Government grading-rooms. From each truck of wheat which enters Winnipeg a sample is taken. This is placed in three tin boxes. The Government authority keeps one, and, if required, one goes to the seller and the third to the buyer.

After being graded, which consists in finding the percentage of stockage (foreign seeds and dirt) present, and then classifying the clean wheat which remains (*e.g.* No. 1 Manitoba, weighing 60 lbs. to the bushel and free from disease), a certificate is made out for the truck-load. The sample tin, containing a card with full information of the grain, is then stored for a time in case of dispute. By this method of Government grading a wheat merchant in any part of the world knows exactly what he is buying. This, however, is not the case with American wheat. Apparently each State in the U.S.A. has its own grading standards, and this affords an opportunity of mixing the different lots at the ports, to the advantage of the distributor from the ports.

A geological party was taken by motor-cars to Stony Mountain, about eight miles north-west of Winnipeg. The excursion was under the direction of Prof. R. C. Wallace, of the University of Manitoba, the object being to study the Upper Ordovician rocks of the district. In the large quarry and in the road-section below it the sequence observed was, in ascending order, as follows: (*a*) mottled purplish and yellow-brown shales, (*b*) yellowish clayey and calcareous beds, and (*c*) dolomitic limestone. The shales proved to be very rich in fossil remains, the fauna including stromatoporoids, corals, bryozoa, brachiopods, gastropods and trilobites. Among the fossils collected the following well-known forms were obtained: *Streptelasma trilobatum*, *S. rusticum*, *Dalmanella testudinaria*, *Dinornis proavita*, *D.* (*Hepertella*) *subquadrata*, *Leptæna nitens*, *Rhynchotrema capax*, *Strophomena incurvata*. At the top of the clayey calcareous beds large specimens of the coral *Favosites* were found in the floor of the quarry. The dolomitic limestones are extensively quarried for road purposes. A few fossils were collected, including *Beatricia* from near the top of the section. In addition the many curious markings and structures, possibly of organic origin, gave rise to active discussion.

Another small party was taken to visit the municipal hydro-electric power plant at Point du Bois, on the Winnipeg River, 78 miles from the city. The existing capacity is 67,100 h.p., and new units were in process of installation to increase the capacity to 88,000 h.p., while a further large increase is planned. The residences of the staff form a collection of attractive and well-constructed wooden houses, with church, school, and hostel for single men. The journey to and from the power station afforded opportunity to observe the outer range of settlement, and one 'shack,' inhabited by a Russian, was pointed out as the last settlement between Winnipeg and Hudson Bay. Near Winnipeg the outward route passed through a Galician settlement, in which the lots were small and devoted to the cultivation of fruit and

vegetables for the city market. The market-carts, primitive in construction, and many obviously home-made, were seen laden with vegetables, etc., and drawn by one or two horses. The women help on the land, and many were with their husbands going to the market.

Beyond the Galician settlement were ordinary farms, and it was evident that efforts were being made to establish mixed farming. Here the area of land connected with a homestead was greater and the house, constructed of wood, was larger than in the Galician settlement. Small townships were passed, and mixed farming seemed to give place to prairie farms, and later to uncultivated land too far from rail and market to attract the settler. The return journey passed through Selkirk and a Ruthenian settlement which was similar in many respects to the Galician settlement, and it was again observed that women were helping in the fields. One of the guides expressed the view that the Galician or Ruthenian peasant is a good settler, in that he possesses all the necessary qualities of industry, perseverance, and thrift.

The main body of the members was conveyed by street-car to the Manitoba Agricultural College, where, after inspecting the buildings and grounds, they were entertained to luncheon. Addresses of welcome were given by the Mayor of the City and the Premier of the Province, and Sir William Bragg and Sir William Ashley replied on behalf of the Association.

The Manitoba Agricultural College is situated eight miles from the city. The college buildings were erected in 1912 at a cost of $4,000,000, and provide magnificent facilities and equipment for teaching and research in the sciences applied to agriculture. The course for the degree of Bachelor of Science in Agriculture (B.S.A.) extends over a period of five winter sessions. In addition there are shorter courses of two winters' duration in agriculture, domestic economy, dairying and poultry husbandry. A noteworthy feature of all the courses is the thoroughness of the practical training. For example, an abattoir has been erected in the college grounds, and the students receive practical instruction in the slaughtering of farm animals and the dressing of carcasses for market.

In the short time available it was not possible to make a thorough inspection of the work of all the college departments, and attention was therefore mainly confined to the crop and animal husbandry investigations.

The soil is a dark brown loam varying in depth from 6 inches to 3 feet, and resting upon a stiff yellow clay subsoil. The average annual rainfall is about 20 inches, but is often considerably less. Sowing takes place in May, and, as there are only about 100 growing days, prominence is given to the work on early maturing varieties, particularly in the case of maize for silage. Considerable attention is also being given to seed production, as it is the general experience that locally grown seed gives better results than seed from southern districts. Among other experiments inspected were those for the production of winter hardy varieties of Red Clover and Alfalfa, and those with White Mellilit and Sudan Green, etc., for the formation of pasture.

Experimental herds of Aberdeen Angus, Herefords and Beef Shorthorns are kept at the college farm, together with Friesians and Dairy Shorthorns for dairy purposes. Several of the most important British breeds of sheep are also represented. The college authorities are inclined to the view that they have not yet got the breeds of cattle and sheep most suitable for the province, and experimental work in this direction is in progress. Experiments on the production of early-maturing beef and bacon are being carried out and some interesting and valuable results have been obtained.

In its propaganda and educational work a big effort is being made to convince the farmers in the province of the economic advantages of mixed farming. This work is meeting with considerable success.

In the afternoon members made a tour through the city in motor-cars, and were entertained to tea at the Royal Alexandra Hotel by Mr. D. C. Coleman, Vice-President of the Canadian Pacific Railway. The party left Winnipeg at night.

Friday, August 22.—SASKATOON, Sask. (1764 m., 1589 ft.), was reached in the early afternoon. The party was taken by motor-cars to the University of Saskatchewan, and the ceremony of the opening of a new chemistry building took place immediately on arrival.

The opening of this building and the inspection of its fine equipment were followed by a special meeting of Section B (Chemistry), the President (Sir Robert Robertson) in the chair, 108 being present.

The President, opening the meeting, referred to the preceding ceremony of the inauguration of the building in which the meeting was held. He introduced the discussion on *Photosynthesis* by referring to the work of Moore, and pointing out the special interest of the subject for agriculture.

Prof. E. C. C. Baly delivered an address in which he pointed out that 'the presence of formaldehyde has been proved in solutions of carbonic acid after exposure to ultra-violet light. Since formaldehyde on activation by light at once polymerises to give reducing sugars, it is probable that the formaldehyde produced photo-chemically from carbonic acid does the same, and therefore the first recognisable product of the action of ultra-violet light on carbonic acid will be the sugars, the ordinary formaldehyde being produced by the action of the ultra-violet light on the sugars. This has been proved to be the case.

'Independent evidence of the formation of activated formaldehyde is found in the fact that solutions of carbonic acid containing potassium nitrate gave formhydroxamine acid on exposure to ultra-violet, the same compound being formed if ordinary formaldehyde is substituted for the carbonic acid. Further reducing sugars are produced by the action of the silent discharge on mixtures of hydrogen and carbon monoxide.

'Considerable quantities of the reducing compounds have been prepared by the action of light on formaldehyde and the presence of a hexose has been proved by Irvine and Francis.'

Principal Irvine described the chemical examination of Prof. Baly's synthetic product by the method of methylation. The original syrup he found to contain between 9 and 12 per cent. of methoxide groups. It did not contain hydrolysable carbohydrates of the formula ($C_6H_{10}O_5$) nor glucosides nor polysaccharides. About 10 per cent. of hexoses were definitely present, chiefly glucose and mannose, but not galactose.

Prof. C. W. Porter, of the University of California, described very careful experiments, chiefly with very pure carbon dioxide and water in which, when all contamination was prevented, he definitely failed to obtain formaldehyde or reducing sugars. His experiments were almost entirely carried out with gases, whereas Prof. Baly dealt with solutions. Prof. Porter also mentioned a smooth photo-chemical transformation of acetone vapour at 100° quantitatively to CO_2 and ethane, and also the transformation of benzophenone in 50 per cent. aqueous alcohol to benz-pinacol.

After an interval for tea provided by the University, Prof. J. H. Priestley pointed out that photosynthesis in the plant must go like a flash with almost instantaneous formation of starch, without any possibility of the accumulation of formaldehyde, even if it were the intermediate product. He dissented from E. F. Armstrong's view that sucrose was the first sugar formed, pointing out that its variation in amount in darkness and in light, in contrast to the relatively uniform presence of hexose, was good evidence of sucrose being merely a storage product. He believed in separate enzyme machineries, independent of each other, transforming hexose into inulin, sucrose, and starch respectively. These processes must be quite independent of each other, and are characteristic for the particular plant or even for a particular part of a variegated leaf.

Animated discussion followed, in which Prof. Bancroft, Principal Irvine, Prof. Raman, and Prof. Baly took part.

Principal Irvine agreed with Prof. Priestley that sucrose was not a first product, and that formations of starch, sucrose, and cellulose were wholly independent reactions, and mentioned the very rapid condensation of the anhydride of glucose, and also discussed formation of galactose from glucose as a sort of Walden inversion.

Sir R. Robertson moved a vote of thanks to the speakers.

A meeting of Section C (Geology) was also held, at which the President, Prof. W. W. Watts, took the chair and called upon Dr. J. W. Mellor to give an address on *Clays and the Clay Industry.* The lecturer had selected this subject as it was of great local interest. He laid some stress on the harmful influence of those who could not distinguish between bad workmanship and Art. The difficulties to be contended with in the industry were quite great enough without introducing unnecessary factors. He then remarked on the commercial possibilities of certain of the clays in the province, indicating some of the articles for which they might prove suitable.

Prof. W. A. Bone, F.R.S., followed with another topical paper on *Brown Coals and Lignites.* This paper had been communicated to Section B at Toronto, but it was felt that it should be repeated here. An abstract will be found under Section B, Tuesday, August 12 (p. 377).

A joint meeting of Sections D (Zoology) and M (Agriculture) was held, at which Prof. W. J. Dakin delivered a short lecture on *Animal Diseases.* The local research workers are considerably interested in the control of the warble-fly and in the investigation of 'swamp fever' in horses.

The local branch of the Engineering Institute of Canada met engineering members of the party; Sir C. Parsons spoke on the development of the steam turbine, and Prof. G. W. O. Howe on wireless communication.

Through the kind permission of the Board of Trade and the Rotary and Kiwanis Clubs, members were enabled to visit, in motor-cars, the principal points of interest in the city and neighbourhood, including the forestry farm, Normal School, Quaker Oats flour-mills, Government wheat-storage elevator, agricultural experimental grounds, experimental stock-yards, Saskatchewan clay deposits, a flower show, etc., and they were entertained by local ladies to tea at the University. The naturalists of the party were given opportunity to study the surrounding country, and the botanists were particularly grateful for a list of common prairie plants which was supplied to those interested, and helped to solve many points which had been discussed in the course of the journey. The North Saskatchewan River, with its wooded banks lined with glaciated rocks, and its sands containing gold in minute quantity, also attracted attention. Members interested in problems of overseas settlement were enabled to visit some of the houses of the people; in particular, the necessity of personal effort was impressed upon them on viewing a farm which had failed after an attempt to work it through a foreman.

There are two specially interesting lines of work at the Saskatoon agricultural experimental station.

(1) Plant selection and breeding work, with the object of producing early-ripening varieties of maize and winter hardy clovers and alfalfa. If success attends these efforts—and considerable progress has been made—it is hoped that it may prove possible to substitute a 'hoed' crop, such as maize, instead of fallow.

(2) Experiments on the formation of pastures by sowing sweet clover, alfalfa, and western rye grass.

The average farm in Saskatchewan is about 320–480 acres in size. On the straight grain farm—that is, one following the rotation wheat, wheat (or oats) and fallow—one man can work 320 acres with help in the spring and at harvest-time. Only the fallow is ploughed, the fallow wheat stubble being disked two and a half inches deep for the following wheat crop. Thirty-five acres can be disked per day and sowing drills can keep pace with the disc cultivator. The yields are stated to be 30 bushels of wheat per acre and 60 to 70 bushels of oats (34 lbs. to bushel), but this year the appearance of the crop would suggest considerably lower yields.

In the evening the members were entertained at an informal civic dinner in the King George Hotel and the University dining-hall. After this, a meeting was held in Third Avenue Church, when the Premier of Saskatchewan (Mr. C. A. Dunning) and the Chancellor of the University (Sir Frederick Haultain) welcomed the members, and an address was given by Dr. E. E. Slosson on *Photochemistry and Modern Civilisation.* The special trains left Saskatoon after this meeting.

Saturday, August 23.—The party reached Edmonton, the capital of Alberta (2087 m., 2185 ft.) in the morning, and was escorted to the Government Buildings, where it was received by the Premier of Alberta (Mr. H. Greenfield). A series of meetings then took place in the University.

Section A (Mathematics and Physics).

Sir Richard Paget—*Nature of Speech.*

Prof. A. S. Eddington—*Interior of Stars.*

Sir William Bragg—*Crystal Structure.*

Section C (Geology). (*See* below.)

Prof. J. A. Allan—*Local Geology.*

Prof. P. G. H. Boswell—*The Trend of Recent Work on the Petrology of Sedimentary Rocks.*

Prof. W. A. Parks—*Searching for Dinosaurs in Alberta.*

Dr. J. W. Mellor—*Ceramics and the Clay Industries.*

Prof. W. A. Bone—*The Coking Constituents of Coal.*

Sections K and M (Botany and Agriculture).

Prof. C. H. Ostenfeld—*Means of Migration of Plants.*

Prof. E. C. Jeffery—*Polyploidy and Allied Phenomena in Relation to the Origin of Species.*

Sir Robert Greig—*Economic Trend of Animal Husbandry.*

Dr. A. W. Borthwick—*Forest and Climate.*

Prof. W. W. Watts, F.R.S., President, opened the session of Section C in the Geological Department. The first communication was a description of the general geology of the province by Prof. J. A. Allan. In the short time at his disposal Prof. Allan carried his audience over a wide area by means of diagrams and sketches. He thus indicated the possibilities of the province in regard to mineral wealth and, at the same time, some of the problems confronting the geologist in that part of Canada.

Prof. P. G. H. Boswell followed with his paper on *The Trend of Recent Work on the Petrology of Sedimentary Rocks.*. The following is an abstract :—

The history of investigations on the petrography of sedimentary rocks shows that the phases passed through included the following : (*a*) The simple description of adventitious minerals in recent sands and gravels ; (*b*) accounts of those of more ancient rocks ; (*c*) the description of lateral variation or constancy in mineral assemblages of strata, deductions regarding source, drainage, etc., being made ; (*d*) the utilisation of peculiarities of petrography for establishing relative age or for correlation over limited areas. Some light was obtained on the relative stability of various minerals in sedimentary rocks, but much work still remains to be accomplished. Descriptions of lithic and textural characters accompanied the more special work outlined above.

Certain principles seem to have emerged from the detailed study of the complete series of British formations, aided by examination of numerous extra-British deposits. Amongst these principles are :—

1. Sediments derived from crystalline rocks display greater variety in their constituent minerals (both in species and varietal characters) than those derived from pre-existing sediments.

2. The variety of minerals in any one sediment (except as in 3 below) varies inversely as the distance from the source. Simplification and, in part, sorting are more effective as transport increases.

3. The proportion of heavy minerals varies with the mechanical composition of the deposit. Sediments of coarse grade even near to their source may show but few heavy detrital minerals.

4. Colour-bandings due to minerals (pay-streaks) indicate the action of wind and water currents and are therefore marginal features.

5. The erosion of a rock-succession results in a reversal of the order of the characteristic constituents in the sediments produced.

6. A general tendency exists for progressive mineralogical simplification and increasing uniformity with decreasing age in a series of beds laid down in a marine basin. More variety occurs in marginal deposits and less in those occupying the middle of the basin.

7. Least petrological variation is found in marine sediments of isopic facies and of uniform and similar grading, deposited at some distance from a shore-line or towards the close of a period of continuous sedimentation.

8. More variation is noted in deposits formed in epicontinental seas, especially under archipelago conditions.

9. Most variation is observed when sediments have been laid down under continental or entirely terrestrial conditions, in which cases isolated basins of deposition are formed.

10. Tectonic movements usually result in petrological 'rejuvenation' of sediments. The converse proposition is also of much value.

11. The detrital minerals of sediments (exclusive of deep-sea deposits) are dominantly the 'stress-minerals' of Harker. The anti-stress minerals are relatively less stable.

12. Unconformities are frequently marked by petrological as well as by palæontological breaks.

Examples are cited in illustration of each of the various principles outlined above.

Prof. W. A. Parks, dealing with the search for Dinosaurs in Alberta, stated that, as the party had passed through some of the country where in former ages Dinosaurs had wandered, he could not do better, in a general lecture, than describe the work of an expedition he had organised to discover and excavate the remains of certain of these interesting creatures. By means of lantern illustrations he showed how an expedition into the Bad Lands was arranged and how roads had to be made, often for miles, to haul out the blocks of stone in which the remains were sealed. The actual cleaning up of the skeletons was not attempted until the material was assembled in the laboratory, for it was impossible to spend the necessary time to effect this on the actual expedition.

Those who did not take part in these meetings were given ample opportunity to view the city and neighbourhood. Those who remembered the city from their visit during the Western Excursion of 1909 were struck with the evidences of growth and civic advancement since that time, and particularly with the extension of educational institutions, exemplified not only by the stately University buildings, but also by the schools and their excellent appointments. Special geographical, geological, and agricultural parties were formed. Among the points of interest which impressed the visitors were the striking situation of the city, high above the banks of the North Saskatchewan River, and the evidence of the varied resources of the locality. A coal working was visited by some of the members, and information was obtained as to the extensive coal-field underlying the district. The timber resources were pointed out, as also the special agricultural interests of the neighbourhood, notably the reclamation of land which had recently been *muskeg* (peaty bog, choked with stumps and old timber), the market-gardening or 'truck' lands, cultivated in particular by Chinese, the active cultivation of flowers, and the agricultural exhibition grounds.

An interesting experiment is in progress at the experimental station with the object of ascertaining whether alfalfa if sown down in place of a fallow can be relied upon to stand for several years. The experimental plots laid down in 1918 are still standing remarkably well. Moreover, it has been found possible to cultivate between and across the rows of alfalfa in the fall and spring and so keep the land clean. The preliminary results so far obtained indicate that wheat after alfalfa is almost as satisfactory as wheat after fallow. Two cuts per annum are obtained from the alfalfa, with an average yield of eight tons of green feed (30 per cent. dry matter). It has been found that more frequent cuttings tend to weaken the crop.

Valuable experiments are also in progress on the growth of fodder crops for pigs. Maize, peas, barley, and a mixture of maize and peas are being grown for this purpose. When the crops reach the stage at which the grain begins to harden the pigs are turned in. It is claimed that the crop losses are small, so that the pigs can be

maintained outdoors and thrive remarkably well until the December shows come. A small shelter-shed for the pigs is provided on each plot.

The visit to neighbouring farms impressed members with the magnificent crops and attractive homesteads. The Alberta farmers have been gradually turning from 'straight' wheat-growing to mixed husbandry involving the introduction of livestock. Stock are now to be found on a large proportion of the farms. An excellent flock of Oxford Down sheep on a 160-acre holding was inspected during the afternoon, and also a herd of 500 pigs and 40 Ayrshire cows on a 1200-acre farm.

The visiting members were entertained to luncheon by the City of Edmonton at the Macdonald Hotel, when they were welcomed by the Mayor, and to dinner in the evening by the University of Alberta in the University dining-hall. A public evening meeting was held in the Convocation Hall of the University, when the members were welcomed by President H. M. Tory, and short addresses were delivered by Sir John Russell on *Eighty Years of Wheat Growing*, by Sir William Beveridge on *The Economic Outlook in Great Britain*, and by Dr. J. S. Flett on *The Functions of a State Geologist.* An informal conversazione was also held in the University before the members left at night to rejoin the trains.

Botanical Excursion, Edmonton–Banff.—A party of botanists left the main excursion at Edmonton and, leaving the city in the morning of Sunday, August 24, travelled by motor-cars to Calgary (205 miles). The Dominion experimental farm at Lacombe was visited on the way, and the party was entertained to tea by the Director. Occasional timbered hollows varied the monotony of the prairie, and the view of Red Deer in its river valley was also a welcome contrast. Calgary was reached between 10 p.m. and midnight. The next morning (August 25) was spent in Calgary, and after luncheon the party set out for Banff, 87 miles distant—a fine ride towards the mountains, first across prairie-land, with extensive oat crops and patches of grazing land in the hollows; then through more undulating ground with low woods into the foot-hills, and then the National Reserve and the magnificent mountain gorge through which the Bow River runs from the Banff Valley.

The night was spent at the Middle Springs Camp on the slope of Mount Sulphur, 800 feet above Banff. Next morning (August 26), after a visit to the Alpine Club above the camp, whence magnificent views of the valley and its encircling mountains were obtained, the party motored to Storm Mountain Camp, at the head of the Bow River Valley, 1000 feet above Banff, and shortly after took the trail through the woods up Boom Mountain to Boom Lake, at the foot of the Boom Mountain glacier. The lake and its surroundings recall Lake Louise on a small scale. After two hours of botanic investigations along the lake-shore came a walk back down the trail and a short ride to Storm Mountain Camp, where the night was spent. On Wednesday, August 27, a ten-miles' drive over the watershed between Alberta and British Columbia to Marble Canyon was followed by a walk up a forest trail along the Vermilion River to a bluff which afforded a fine view of the river gorge. Some of the party visited the old Indian paint-pots, the ochre-beds which supplied the war-paint; others ascended the mountain, following a snow-slide, to the scree. On returning, Major Robertson, the engineer of the new Windermere Road, led the party for a ride of twenty miles along the valley, indicating various view-points with fine vistas of valley and mountain. The night was spent at Marble Canyon Camp. On Thursday, August 28, the party motored to Lake Louise, and then walked up to the moraine and the foot of the glaciers; a number of interesting alpine plants were gathered. The night was spent at Middle Springs Camp, and next morning (August 29) the botanists joined the main party at Banff Station. The excursion was most enjoyable and profitable, and a large number of interesting plants were seen and gathered. Hearty thanks were extended to Prof. F. J. Lewis, of Edmonton University, who arranged the excursion, to his colleagues and friends who generously lent their cars, and to Mr. West, the Bursar of the University, and the three students who drove the cars and kept them in condition; also to Mr. Sanson, Director of the Banff Museum, who led the party on some of its walks.

Sunday, August 24.—The trains reached Jasper (2323 m., 3470 ft.) in the morning. Here the members were guests of Sir Henry W. Thornton, K.B.E.,

President of the Canadian National Railways. They were conveyed by cars to Jasper Park Lodge, the mountain hostel of the C.N.R. in Jasper National Park, Alta., and by car, on foot, or on horseback the majority proceeded thence to Maligne Canyon. Proceeding, the trains stopped at the view-point for Mount Robson. The weather here, and for the rest of the day, was unfavourable, but it subsequently cleared, and during the visit to Vancouver, and for the rest of the journey through the mountains, it was perfect.

Monday, August 25.—VANCOUVER (2854 m., 16 ft.) was reached in the morning. A civic reception took place at the C.N.R. station, and members enjoyed a short tour of the city and Stanley Park as guests of the Automobile Club of British Columbia. The party then divided, some members proceeding immediately to Victoria, B.C., while others deferred their departure until the night boat.

The members remaining in Vancouver were entertained to a civic luncheon at the Hotel Vancouver, when they were welcomed by the Mayor (Mr. W. R. Owen), and short addresses were delivered by Prof. J. W. Gregory and Prof. J. G. Smith. In the afternoon members interested in lumber industries were offered a visit to the Fraser Lumber Mills, conducted by Prof. H. R. Christie. A geological party, led by Prof. S. J. Schofield, visited the Capilano Canyon, a waterfall gorge cut back during post-glacial times through granite rocks. Those interested in anthropology and archæology visited the settlement of Squamish Indians on the north side of the harbour, under the guidance of Mr. Harlan I. Smith, of the Victoria Memorial Museum, Ottawa. Botanists, agriculturists, and others inspected the new University site and buildings and were entertained to tea at the Botanical Gardens. Visiting ladies were received by the Women's Canadian Club at the Hotel Vancouver, and Dr. F. C. and Mrs. Shrubsall spoke on *Physical and Mental Welfare*. In the evening two public meetings were held :—

(*a*) At Wesley Church. *Chairman :* Mr. R. E. MCKECHNIE, Chancellor of the University of British Columbia ; *Speakers :* Prof. G. W. O. HOWE, on *Recent Developments in Radio-telegraphy* ; Dr. A. W. BORTHWICK, on *Recent Progress in Forestry*.

(*b*) In the Physics Lecture Room, University of British Columbia. *Chairman :* Dean R. W. BROCK, University of British Columbia ; *Speakers :* Prof. W. T. GORDON, on *Physical Features which characterise Gem Stones* ; Prof. W. W. WATTS, on *A Buried Landscape*.

The members who had left by the morning boat for VICTORIA, the capital of British Columbia, on Vancouver Island, reached that port about 3 p.m. They were entertained to tea in the exquisite gardens of Government House by the Lieutenant-Governor of British Columbia, Mr. Walter C. Nicholl, and at a civic dinner in the Empress Hotel, when the Mayor (Mr. R. Hayward) and Dr. Plaskett welcomed the Association party, and the President (Sir David Bruce), Mr. F. E. Smith (General Secretary), and Prof. F. C. Donnan replied.

A party of botanists had been met on arrival at Victoria by Mr. C. C. Pemberton, who conducted them by motor-car to various points of botanical interest. On the sea-beach were found stranded specimens of the giant brown seaweed *Neurocystis*. This grows attached to rocks or stones by a branched holdfast from which extends a long stipe expanding into a bulbous end bearing streaming leaf-like fronds. An average plant measured by a member of the party was 24 ft. in length, exclusive of

fronds and holdfast. The party then visited a wood where Mr. Pemberton pointed out examples of tree stumps (*Abies grandis*) in which the cut surface had been completely healed over by the formation of a cushion-like mass of tissue. He claimed that this process may be made possible by means of natural grafting of the roots of adjacent trees. Passing through woods consisting of the native oak, *Quercus Garryana*, a dry grassy upland region was reached, where much rock was exposed. From the rock crevices were obtained *Selaginella rupestris*. Mr. Pemberton called attention to the abnormal growth of certain oak-trees, whose trunks had formed flattened and buttress-like expansions when in close contact with rock surfaces.

Other members of the party, on arrival, had visited the Museum, and were shown round it by the Curator, Mr. Francis Kermode, and by Dr. C. F. Newcombe, the veteran ethnologist. The Museum was again opened in the evening up to a late hour, and advantage was taken of this courtesy. Though of small size, the Museum is most interesting, and contains valuable collections, chiefly ethnological and zoological. The ethnological series illustrates the old native life not only of the Indians of Vancouver Island, but also of the neighbouring coastal peoples of British Columbia. Many of the specimens were collected before the culture of the natives had undergone extensive modification through contact with Europeans, and several unique examples are included. Industries, arts, and native cults are well illustrated, and the archæology is represented by a fine series of stone implements, some of which were already obsolete many generations ago. Dr. Newcombe explained the specimens very fully. A handbook to the ethnological collection has been published, with illustrations of the more important exhibits. Zoologically, interest centred chiefly upon two exhibits. A peculiar variety of bear (*Ursus Kermodei*), white but not albinistic, and restricted, apparently, to one island off the British Columbia coast, is represented by three or four specimens in the Museum (a live example is exhibited in the public park). It appears to be allied to the black bear and not to the polar bear. Traces of brownish tints appear amidst the general white coloration. This bear has been given specific rank and has been named after the describer, Mr. Kermode. Another exhibit of great zoological importance consists of bones and cartilages of the only partially atrophied hind limb of a Humpback Whale (*Megaptera*). As far as is known, this is the only instance on record of a whale possessing the remains of external hind limbs. These limbs are said to have projected four feet beyond the whale's sides. Unfortunately the whale had been partly flensed before the peculiar atavistic abnormality was noticed, and it was only possible to preserve the limb bones of one side.

On the following morning a small party was taken by Dr. Newcombe to visit the remains of some old Indian burial cairns near Victoria, and also some Indian village sites near Esquimalt, which are chiefly indicated by the remains of defensive trenches and extensive shell-heaps or kitchen-middens.

The party was invited by Mr. Badcock to visit his fine and valuable private collection of native basketry. The various local basketry techniques are admirably represented and the collection is remarkably complete and instructive.

Physicists and other members not otherwise occupied in the evening visited the Astrophysical Observatory, under the guidance of Dr. Plaskett, and were given an opportunity to look through the great reflecting telescope.

A proportion of the members returned to Vancouver by the night boat.

Nanaimo.—A zoological party visited the Marine Biological Station at Nanaimo, Vancouver Island. This station has been a famous collecting ground for many years, largely through the interest of the Rev. Mr. Taylor. In 1909 the actual station was founded as one of those under the direction of the Biological Board of Canada. At present there are several buildings, and, although the accommodation is not large, there are excellent facilities for obtaining material and for research. The library is small and is deserving of all the help which can be granted it in the way of gifts of literature. The great assets of Nanaimo are the wonderful fauna and the remarkably fine situation of the station—fine not only from the point of view of obtaining material but also from the scenic and health aspects. The success of the excursion was largely due to the combined work and hospitality of Prof. Clemens (the Director) and Mrs. Clemens, Prof. O'Donoghue (Winnipeg) and Mrs. O'Donoghue, and Dr. Collip, to whom the party was greatly indebted. On the afternoon of its arrival all the party went out tow-netting. The following morning was devoted to dredging and shore collecting. As the sea was calm the work was very successful.

Tuesday, August 26.—A number of the members visited Victoria on this day only, arriving in the morning and leaving at 2.15 p.m., but they

were able to see the city and peninsula, Butchart's Gardens, the astrophysical and meteorological observatories, and other points which had also been visited by the earlier party.

The programme for this day at Vancouver included an excursion by steamer to Howe Sound ; a visit of engineers to Lake Buntzen as guests of Mr. George Kidd, of the British Columbia Electric Railway Company, conducted by Prof. H. Vickers; and botanical trips in the neighbourhood of the city, conducted by Profs. A. H. Hutchinson and J. Davidson.

Howe Sound is a magnificent fiord surrounded by mountains, high and steep. Some of the party went to the head of the fiord at Squamish, where they saw the site of a recent Indian village, and learned that some of the distant mountain-peaks seen were still without official names.

A geological party, conducted by Profs. Schofield and Christie, under the auspices of the Canadian Institute of Mining and Metallurgy, landed at the Britannia Copper Mines. They were received by Mr. Browning, managing director of the mine, and proceeded in a truck drawn by an electric locomotive to the foot of the great incline, at a height of some hundreds of feet. The truck was then hauled by a cable up the incline, about 1000 feet at a very steep gradient. Here another electric locomotive took the truck along a zigzag line several miles in length and gradually ascending about 500 ft. to the mouth of the main adit. Here the Company entertained the party at luncheon at the office situated in the main mining village, a group of houses of which many have lawn-tennis courts built out from the hillside. After lunch, Mr. Moore, manager of the mine, took the party some distance into the mine with the aid of an electric locomotive. Arrived at the shaft the visitors were lifted another 1000 ft., and so came out on the hill-face where the ore body was being worked in the open, both rock and ore being dropped into lower levels in the mine. At this point copper was being recovered from the mine-walls by means of scrap-iron.

Most of the ore is crushed inside the mine and the ore discharged below the incline into the mill, through which the party descended the last few hundred feet to the steamer. The process used is flotation solely, and by this means the ore is concentrated from an average of about 1·7 per cent. up to 17 per cent. in the first instance, and later to 23 per cent. by the removal of pyrites.

Cordial votes of thanks to the Company, the managing director, the manager, and the staff, and to Prof. Schofield, were passed by the party before embarking.

Botanical members were conducted by Prof. Hutchinson, of the University of British Columbia, through part of Stanley Park, which is a forest area composed of coniferous trees of great age and size. Overshadowed by these is a dense wealth of undergrowth consisting of trees and shrubs, beneath which a luxurious growth of ferns and other plants abounded. The chief coniferous trees were *Thuja plicata, Pseudotsuga Douglasii*, and *Tsuga canadense.* The party was much impressed by the height and girth of many of these trees, exemplified not only by living specimens but by wrecks and stumps of former great ones. Tracts of swampy ground occurred in which the most notable plant was the skunk cabbage. In the more open regions *Spiræa* and *Aruncus* were plentiful.

In the afternoon the Botanic Garden near the new University buildings was visited. Prof. Davidson showed an interesting collection of the shrubs and trees of British Columbia. An interesting plant new to most of the visitors was the parasitic *Arceuthobium* (allied to mistletoe) growing on *Thuja.* An experiment was seen in growing Ginseng and other medicinal plants under artificial shade devised to imitate a forest canopy.

Engineering members viewed the sawmills of the Canadian Western Lumber Company.

At a Rotary Club luncheon in Vancouver, Dr. Ivy Mackenzie spoke on *Physiological Discoveries of Importance to the Man in the Street.* A visit to the Vancouver General Hospital took place, and in the evening the President, Sir David Bruce, met members of the Vancouver Medical Association.

Mr. O. H. T. Rishbeth visited New Westminster, B.C., at the invitation of the Kiwanis Club in that city, and gave an address on *Modern Geography, with special reference to its functions in the Dominions,* to an audience of the business and professional classes. He explained the nature and methods of modern geography as a régime of scientific thought and investigation, and then dwelt in more detail upon

its functions and its potentialities for service in young communities in rapidly developing territories. Special emphasis was laid on that practical aspect of the subject under which geography may be regarded as the science of settlement.

Wednesday, August 27.—The special trains, having been transferred to the Canadian Pacific station at Vancouver, left on the lines of that Company in the early morning. Fine views were obtained of the Fraser Canyons, and later in the day the journey from Lytton to Kamloops, with a brief stop at Ashcroft (3057 m., 1004 ft.), afforded an interesting glimpse of a semi-arid country.

The topography, the vegetation, and the human activities all reflected the influence of the insufficient but obviously at times torrential rainfall. The slopes were deeply ravined and showed all stages in the development of earth-pinnacles, called locally 'hoodoos.' In places open stands of the bull pine, with its short branches and stout, stiff leaves, were observed, but as a rule the incomplete plant-cover consisted of sage-brush, a prickly form of *Salsola kali,* and other grey-leaved plants of similar size, with small, spreading, starfish-like mats of prickly pear in patches between the larger forms. At Ashcroft, as at the other villages, a small amount of tree-planting had been done, poplar and ash-leaved maple being noted. Some irrigation work was observed, but near the railway line there were few signs of cultivation, though fruit-growing is said to be very successful in some parts of the dry belt, while potatoes are grown intensively near Ashcroft.

The journey now, and until Friday, August 29, continued through the magnificent mountain scenery of the Canadian Pacific main trans-continental line, and, thanks to the judicious arrangement of travelling hours, little was missed. GLACIER (3273 m., 3778 ft.) was reached on Wednesday evening, and the night was spent there.

Thursday, August 28.—The glaciers and mountains at Glacier were viewed in the early hours of a very beautiful morning.

A joint excursion of representatives of the Geology and Geography sections was arranged to visit the Glacier. The party viewed a glacier which is retreating up its valley. In front the smoothed pavement was well marked, but the ice itself was perhaps more interesting. It was blue to the base, not particularly transparent, and with little or no mud embedded into it. On the surface, however, for a height of 10 to 12 ft. the surface was very muddy. This was no doubt due in part to dust blowing along the valley and coming in contact with the wet face of the glacier, and in part to the gradual accumulation on the surface of englacial mud which, when it thawed out on the surface, likewise adhered to the wet face.

It was not possible to arrange any official excursion from Field to Mount Stephen, but some of the geologists made one by omitting the visit to Lake Louise (below), travelling from Field by ordinary train, and rejoining the main party at Lake Louise station. To the geologist travelling in Canada there are certain fixed points round which he tries to arrange his itinerary, and one of these is Mount Stephen, the name of which has been made famous by the researches of Dr. Walcott. The well-known fossil beds of Middle Cambrian age are exposed about the 7000-foot level; practically every slab of rock had specimens of trilobites upon it, and numerous fine examples were collected.

The main party, after crossing the Great Divide (5338 ft.), proceeded direct to LAKE LOUISE station (3379 m., 5050 ft.), and were conveyed thence to the lake itself (5670 ft.). The late afternoon and evening were spent here, and the extraordinary beauties of the lake and its neighbourhood were appreciated to the full, though some of the members recalled with regret, from the visit in 1909, the appearance of the northern end of the lake before the present hotel building and surroundings were brought into existence. The trains stayed for the night at the station.

A small party proceeded in advance of the main body, to visit the ranch belonging to H.R.H. The Prince of Wales, near High River. The motor drive of over 70 miles

across country from the main line was made easy and instructive by the courtesy of citizens of Calgary, and the visitors were hospitably entertained at the ranch by Mr. and Mrs. Carlisle, and given opportunity to study the pedigree stock and the working of the farm. On the return journey the rapid emergence of a steep atmospheric depression from the mountain region into the rolling country was accompanied with heavy local hailstorms.

Friday, August 29.—The well-known Rocky Mountain resort of BANFF (3414 m., 4537 ft.) was visited in the morning. Here, as recounted above, the botanical party which had left the main excursion at Edmonton rejoined. From Banff, the trains left the mountain region, the weather breaking as they did so.

CALGARY, Alta. (3496 m., 3438 ft.), was reached in the afternoon, the visitors being received by the Mayor and other leading citizens, including a reception committee of the Calgary Branch of the Engineering Institute of Canada. The Imperial Oil refineries, Calgary Steam Power plant, C. P. railway shops and irrigation dam, etc., were shown.

Saturday, August 30.—At REGINA, the capital of Saskatchewan (3957 m., 1895 ft.), three hours were spent at midday. The visitors were entertained at a civic luncheon, and addresses were given by Prof. D'Arcy W. Thompson, Sir Thomas H. Holland, and Dr. Marion Newbigin.

The depression already mentioned was now travelling abreast of the trains, and giving rise to dust-storms or heavy showers.

Sunday, August 31.—A stop was made at KENORA, Ont. (4339 m., 1090 ft.), on the Lake of the Woods. The party was received by leading citizens, and excursions on the lake were arranged, the weather fortunately improving. A welcome-card from the Rev. E. Diamond, rector of St. Alban's Anglican pro-cathedral, was especially appreciated.

A geological party proceeded in two launches through the Devil's Gap to the island occupied by the M.L.A. Camp. Here they examined numerous exposures of the rocks of the Keewatin Group, of which apparently the island is mainly composed, and noted some rather sheared amygdaloidal lavas and some basic lavas and tuffs with occasionally more acid types. In particular at one point a conspicuously banded rock had resulted from the injection of acid material into the basic. Later the party proceeded to Sultana Island. The slate and cherty beds of the Keewatin were first examined, and then the hill was climbed in order to observe the contact of the granite with the Keewatin rocks. Pillow structure was still discernible in the Keewatin lavas, which in places near the contact were brecciated and injected by these fibres of granitic magma. Next, the site of a gold-mine, no longer worked, was visited. According to Dr. Bruce (the leader of the party) the granite is only a granite at its margin, and in the interior has given rise by differentiation to a felspar pophyry rock rich in felspar phenocrysts. The vein worked lies at this locality along a well-marked belt of shearing at the junction of the felspar pophyry with the granite, and some members of the Section were disposed to consider these two rocks as separate intrusions rather than differentiates of the same rock mass. Some later dykes termed lamprophyres were also examined.

The zoologists had also a special launch expedition to one of the islands, in the course of which tow-nettings were made (the plankton being abundant) as well as collections on the shore. Other members visited an Indian school on the lake, where, under a priest of the Roman Catholic Church, girls from about six to sixteen years of age are educated. Some speak both English and French, and the native speech is not used during term-time.

Monday, September 1.—A stop was made at the ' twin cities ' of FORT WILLIAM (4632 m., 616 ft.) and PORT ARTHUR, Ont., at the head of navigation on Lake Superior. Members inspected the harbour and the huge elevators in which grain from the western fields is collected, in transit

from the railway trucks to the lake steamers. An informal reception was held at Port Arthur.

A geological party was conducted to Mount M'Kay and proceeded up the mountain, following the trail made by the Indians, and noting *en route* the water-worn pebbles of the old beach of Lake Algonquin. A pause was made to examine an excellent exposure in the Animikie slates and greywackés, and the generally unaltered character of the ancient sediments was a matter for comment. Curious markings were observed on some of the bedding planes, and these were considered as possibly due to mud flowage. A wall-like mass of diabase 30 ft. in thickness was observed running up the hill almost parallel with the trail, and shortly afterwards the contact of the Animikie beds with a thin sill (15 ft.) of diabase was passed. At the top of this sill there is a platform due, no doubt, to differential erosion of the Animikie and the igneous rock, and here the surface features of the sill and its effect on the overlying Animikie beds could be studied. These appeared to be hardened and occasionally showed traces of spots, but only in the immediate contact. Above these sediments, and crowning the hill, the director, Dr. Tarton, pointed out the great 200-ft. sill of diabase to which doubtless the mountain owes its preservation.

Various features were shown from this point of vantage, notably the old brick-kilns (where formerly bricks had been made from the Animikie slates, an index of their plastic nature), and the great expanse of the old Lake Superior beach, 830 ft. above sea-level, the present level of the lake being at 600 ft.

The nature of the Animikie slates was discussed, and Dr. Tarton expressed his belief that their high content of potash and soda was indicative of a pyroclastic origin.

A quarry was next visited, where the iron formation below the Animikie slates was well seen. These beds consist largely of chert, together with some iron-bearing rock, either silicate or carbonate. A vein of silver ore occurs at this point along a line of fault which brings the Animikie slates against the iron formation. There has been considerable mineralisation here, and amethyst, quartz, barytes, and pyrites were all present in abundance, as was also the highly carbonaceous anthraxolite.

Leaving this quarry the party next visited a road exposure at the junction of John Street and Winnipeg Avenue. The rocks seen here were at a still lower horizon in the Animikie, and showed crystalline limestones, calcareous conglomerates and chert beds, the relation of which to each other appeared to be much confused. The chert could clearly be seen running both vertically and horizontally through the calcareous members.

Tuesday, September 2.—The trains, having lain overnight at Port Arthur, made short stops at some points on the north coast of Lake Superior, in order that members might see something of this beautiful but little visited district.

At Coldwell the geologists examined the famous exposures of nepheline syenite visible along the railway track.

Proceeding east, the normal syenite was first seen, then a rock containing abundant nepheline with some hydronephelite in places, and, continuing east, the rock seemed to take on gradually all the characters of an essexite. In places the red hydronephelite was most conspicuous. On the way back a camptonite (?) dyke was noticed cutting the nepheline syenite, and passing the station the coarse-grained rocks of the cutting west of it were studied. The rock here was seen to be of very coarse grain, the felspars often attaining a very large size; it seemed to approach a laurvigkite in general composition.

Wednesday, September 3.—At SUDBURY, Ont. (5185 m., 857 ft.), a stop was made in order to visit some of the mines in the vicinity: from this area comes the greatest output of nickel in the world and an important output of copper.

The three companies operating in the Sudbury area, in order of seniority, are the International Nickel Company, with offices at Copper Cliff; the Mond Nickel Company, at Coniston, and the British America Nickel Corporation, at Nickelton. The ores, which consist essentially of pyrrhotite and copper pyrites, are reduced to a matte containing approximately 80 per cent. of the metals, nickel and copper. The International Nickel Company refines its matte at Port Colborne, Ont., not far

from Niagara Falls, with the exception of that which is used in the production of money metal at Huntington, W. Virginia, where malleable nickel is also made. The refinery of the Mond Company is at Clydach, near Swansea, in Wales. The matte of the British America Corporation is refined at Deschenes, Quebec, not far from Ottawa, Ontario. Each company has its own refining process. These processes differ greatly. While the International Nickel Company produces electrolytic nickel, most of this metal is obtained from the matte by means of the well-known Orford process of smelting. In the Mond process the nickel is extracted from the roasted matte, in a state of fine division, by carbon-monoxide gas. The British America Corporation's refining process is an electrolytic one known as the Hybinette.

About fifty of the party left the special trains at Sudbury to travel by ordinary train direct to Montreal or Quebec, there joining steamers for England.

Thursday, September 4.—The arrival of the special trains at TORONTO (North Station) in the morning brought the excursion to an end, after a journey of 5396 miles by rail.

The foregoing notes cannot purport to indicate fully the manifold interests of the journey. For example, so numerous were the opportunities presented to all the members of the Association of observing what is being done to utilise the natural resources of the Dominion that it was unnecessary for the economist members to arrange a special series of visits or expeditions. At Cobalt, Kirkland Lake, Timmins, Iroquois Falls, and elsewhere, the conditions and types of labour attracted their attention; and they were also peculiarly interested in the grain elevators and in the whole mechanism of wheat transport from West to East. A special visit, however, was paid by some of them to a salmon cannery at Vancouver; while individual members were invited to address gatherings of business men at Winnipeg and Victoria, and were also shown the welfare institutions of Winnipeg. It is hardly necessary to add that all members interested in education had an unique opportunity of studying the remarkable developments in that direction which are taking place through the universities of Manitoba, Saskatchewan, Alberta, and British Columbia, as well as in the schools. Reverting to the special interests of the biologists, it may be observed that, in addition to their visits and side-excursions to which reference has been made, both botanists and entomologists used every halt, however brief, during waking hours, to descend from their train in order to collect in the vicinity of the track.

Members who went direct from the British Isles to Toronto and back, and made the western excursion, travelled in all a distance of approximately 11,700 miles.

NOTE.—Further particulars regarding the engineering interests of the journeys will be found in *Engineering*, October 10, p. 506, and October 17, p. 539 (1924), and in *The Engineer*, September 5, p. 268. The last article refers in particular to the journey made before the meeting by some of the engineering members from Montreal up the St. Lawrence River, and to Brockville, Ont., when the locations of proposed hydro-electric schemes, subsequently discussed in Section G, were viewed. This party were guests of the Montreal Harbour Commission, and of the Ontario Hydro-electric Commission, whose consulting engineer, Mr. R. S. Lea, organised the journey.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

WEMBLEY, 1924.

The Conference of Delegates of Corresponding Societies met on Tuesday, July 22, 1924, in the Conference Hall of the British Empire Exhibition at Wembley, on the invitation of the Museums Association, which was holding its annual meeting at that time.

The Conference was attended by thirty-four delegates of Corresponding Societies, in addition to members of the Museums Association.

The chair was taken by the Vice-Chairman of the Corresponding Societies Committee, Mr. T. Sheppard, M.Sc., who opened a brief discussion of the recommendations of the Zoological Publications Committee for more uniform size of scientific periodicals. Dr. F. A. Bather, F.R.S., explained the recommendations of the Committee, which are printed in its Report to the Liverpool Meeting of the Association in 1923.

The President of the Conference, Professor J. L. Myres, M.A., D.Sc., F.B.A., then delivered the following address :—

The Conservation of Sites of Scientific Interest.

'*Les longs souvenirs font les grands peuples.*' 'Public utility is not a purely material thing ; national traditions, history and art itself—are they not, in truth, matters of public utility, as much as bridges and arsenals and roads ?' 'To make this feeling real is the task of the civic authorities. . . . It is a matter of intimate duty, of conscience, on the part of city governors, to care for the older monuments, not in amateur fashion as a by-work, but of set purpose, as one of the most important objects of civic administration.' These three expressions of enlightened European opinion in the last century extracted from Professor Baldwin Brown's indispensable book on 'The Care of Ancient Monuments,' hardly need supplement, even to-day, except in one particular. We have, as we have known for some while, to 'educate our masters' ; it is not so widely appreciated that we also have to educate our servants ; that there is only one security that 'city governors' will govern intelligently ; and that is an educated and watchful public opinion, 'a certain force of intelligent belief in the need for agency of the kind' ; and moreover, 'some permanent agency representing the public mind at its best, and always kept in working order.'

Such agencies are of several kinds, all resting on public opinion, which is the ultimate driving force behind them, and court of appeal—positive law, public enactment, or administrative decrees, to be obeyed under penalties ; state-appointed commissions and conservators, with the authority of government and (it may be) legal powers to insist on conformity with the demands of public opinion; and private, unofficial agencies, such as our Societies for the Preservation of Ancient Buildings or for Controlling the Abuses of Public Advertising, or the National Trust for Places of Historic Interest and Natural Beauty. These last, being voluntary associations, can only make it one of their functions to influence public opinion in the direction of a proper respect for monuments or sites worthy of public regard.

It may be of use to delegates, and to the societies which they represent, to review the growth of such public opinion, and define the point which it has reached now. This, at all events, will show most clearly what remains to be done, and how local scientific societies may help to do it.

Four distinct categories of objects are in question here : ancient buildings and other monuments raised by the hand of man ; sites of historic interest on account of some human achievement, such as a battle, or a treaty, which has occurred there ;

districts of natural beauty, preserved for public enjoyment; and places of scientific interest, necessarily also often picturesque, such as haunts of wild life, or instructive geological sections.

Public opinion has moved at different pace in regard to each of these categories.

Ancient Monuments.—In regard to this class of objects, France took action earliest, partly because the Revolution, occurring as late as it did, prolonged a period of wilful revengeful destruction of buildings associated with the 'ancien régime' into the years of a romantic reaction, and of a new conception of the continuity of national history—of Montalembert's *longs souvenirs.* As early as 1810, there was passed a statute for expropriating what were described already as 'national monuments'; by 1830 there was an official inspector-general of such monuments; and in 1837 came Guizot's edict for a 'classement des monuments,' to be carried out by a Commission des Monuments Historiques. Proceeding thus by administrative methods, France had little need of legislative sanction, and her Ancient Monuments Act was not introduced till 1887. In the new kingdom of Greece, on the other hand, what was essential at the outset was a code, on the provisions of which administrative action might be taken; and Greek legislation accordingly begins as early as 1834.

In our own country, no less appropriately, the foundation of voluntary associations for the study and conservation of ancient remains begins early, with the Oxford Architectural and Historical Society and the Cambridge Antiquarian Society, both in 1839. A generation later, in 1869, comes the establishment of the Historical Manuscripts Commission, to facilitate the preservation of the most perishable class of antiquities, and very shortly after comes Sir John Lubbock's Ancient Monuments Bill, introduced for the first time in 1873, and carried by a second reading in 1875, but not placed on the Statute Book till 1882, and ranking therefore in point of date between the Hungarian Act of 1881 and the Turkish Law of Antiquities, enacted in 1884. In the British Act of 1882 provision was made (1) for a schedule of monuments, but it was to be compiled by voluntary advice; (2) for voluntary transfer of a monument by its owner to the guardianship of the Commissioners of Works, with right of access; and for voluntary contributions through the Commissioners, for its upkeep; (3) for purchase of monuments already scheduled, but the Commissioners were given no public funds for the purpose; (4) for an inspector of ancient monuments, but without salary or allowances. The last provision gave official recognition to the devoted labours of Lt.-Gen. A. L. F. Pitt Rivers, who held the office of inspector till 1900. All that this first Act really did was to recognise in principle the national duty of custody and supervision, while safeguarding the vested interests of the owners of monuments whether scheduled or not.

In 1884 the Chester Improvement Act, empowering the city council to veto private encroachments on the city walls, introduced a no less important principle, of local responsibility for the conservators of ancient remains; and in 1887 the formation of the Society for the Preservation of Ancient Buildings by William Morris and his friends initiated a phase of outspoken public criticism of some of the worst, because most well-meaning, devastators of ancient handiwork, the ecclesiastical 'restorers' of churches. On the other hand, it was the omission of elementary precautions by the disestablished Church of Ireland for the repair of its buildings—in spite of the liberal grant of £50,000 for this purpose, in the Disestablishment Act—that was the precedent for the Irish Ancient Monuments Protection Act of 1892, which extended the authority of the Commissioners of Works to monuments other than churches, and assigned an annual grant of £1,000 for upkeep. What would have been intolerable extravagance on one side of the Irish Sea was prudent policy on the other.

The Irish precedent, however, had its influence in Great Britain as well. The establishment of the National Trust for Places of Historic Interest or Natural Beauty in 1895, and the publication of Dr. David Murray's essay on the 'Preservation and Protection of our Ancient Monuments' in 1896, were quickly followed in 1897 by a formal Conference between the London County Council and representatives of archæological societies, with a view to an inventory of local buildings and monuments; in 1898, by the antiquarian clauses in the L.C.C. General Purposes Act, mainly the work of that distinguished administrator and antiquary, Sir Laurence Gomme; in 1899 by the Edinburgh Corporation Act empowering the city council to prohibit the disfigurement of important sites by advertisements; and in 1900 by the first acquisition of an ancient building—a Jacobean house in Fleet Street—under the London County Council's Act already mentioned; by the publication of the first

section of the London inventory, edited by Mr. C. R. Ashbee; and by the passing of the second Ancient Monuments Protection Act, largely based on suggestions from General Pitt Rivers and from the Council of the National Trust, whereby County Councils were given powers similar to those of the Commissioners of Works in Ireland, and empowered both to expend voluntary contributions and to make agreements with other bodies (such as the National Trust) for the maintenance of monuments, and to agree with an owner for public access to such monuments.

For the systematic registration of ancient buildings, the Historical Monuments Commission was established in 1908, and a third 'Ancient Monuments Consolidation Act' was passed in 1913, still further enlarging the powers of the Commissioners of Works, and providing both for the inclusion of other classes of buildings, and for their conservation at the public expense.

Sites other than Buildings hardly needed protection until the spread of large towns and extensive mining and quarrying began to threaten some of them, and others were imperilled through mere inability of private owners to repair them or prevent defacement by 'trippers' and other kinds of hooligan. No systematic action seems to have been taken to preserve them until the National Trust, already mentioned, was incorporated in 1895. This was at first a private society, founded to acquire by voluntary contributions any sites or buildings which might be in danger of the kind here described. But its operations were so efficient and valuable that in 1907 it was incorporated under the National Trust Act, which makes its properties inalienable, and provided for representation of certain learned institutions on its council. At present it owns about seventy separate plots of land, some of considerable extent, eighteen old buildings of architectural or historical importance, and several commemorative monuments of recent date.

Some of the National Trust's properties belong to our last class of sites, the interest of which is neither historical nor artistic, but primarily scientific. They constitute, that is, part of the national wealth and irreplaceable store of scientific material, for advanced study, and for educational ends. Such are the haunts of rare animals and plants, as Wicken Fen; Burwell Fen; Leigh Woods, near Bristol, famous for their nightingales; Blakeney Point in Norfolk, accepted by the Trust under express conditions of preserving the natural flora and fauna; the Ruskin Reserve near Abingdon, 'to be kept for all time in its natural conditions'; and, acquired in the course of the present year 1924, the Farne Islands, a great breeding ground of sea birds, and the ancient deer-park of Hatfield Forest.

But there is still need for vigilance and prompt action wherever danger threatens. Neither private prospectors nor Government departments seem to have learned yet, with any security, that elementary consideration for national well-being of the kind from which our retrospect started. Only last year there was threefold provocation of this kind: the Marconi Company's project of installing, under licence from the Postmaster-General, a great wireless station in the midst of the megalithic site at Avebury; the risk to the amenities of Holmbury Hill through the proposal to instal there a part of the scientific equipment of the Admiralty; and the attempt of the War Office to exclude the public from the neighbourhood of Lulworth Cove, valuable no less for its exceptional beauty than for its classic exposure of jurassic strata. Fortunately, at Avebury and Holmbury Hill wiser counsels prevailed when the inevitable consequences of these plans were explained to the Ministries concerned; the fate of Lulworth, however, is still in suspense, in spite of vigorous representations from the British Association and other learned societies, and in the press.

Delegates will remember the part played in this necessary protest by last year's Conference during the Liverpool Meeting of this Association; and are referred to the Report of the Council to the Toronto Meeting for an account of the steps which are being taken to ensure concerted and immediate action in the event of other incidents of the same kind.

The sole effective remedy, so far as can be seen at present, would appear to be that learned societies even if not immediately concerned in a particular problem of conservation should take concerted steps to promote legislation wider in scope and more strictly worded than the Ancient Monuments Act now in force, for the protection of such sites. Such a Bill should be drafted on the lines of the present Act, but with the proviso that a site or monument once scheduled should be preserved against any kind of disturbance, either by a Government department or by any other person or body of persons, so long as it remains in the schedule; and that the removal of a site or monument from the schedule should only be effected by a deliberate decision of

Parliament, to the effect that national interests demand the defacement of the site, or the removal of the monument in question.

The present risk to all such monuments and sites is that damage once done is in the nature of the case irreparable; that such damage is unavoidable from the first moment of interference; and that unless there is secure provision for public notice, and previous discussion, the intervention of private persons, or semi-official agencies, is usually too late. Public opinion once firmly confronted with the facts, and given time to draw its own conclusions, is usually sound. And whether it be sound or not, there is a strong case for protecting it against prejudgment of the issue by private aggression, or (still more) by rash administrative action on the part of the public's own servants.

A vote of thanks to the President for his address was moved by Mr. P. M. C. Kermode (Isle of Man) and seconded by Mr. W. Dale (Hampshire Field Club).

On the motion of the Chairman, a message of condolence was forwarded to the relatives of the late Sir William Herdman, C.B.E., D.Sc., F.R.S., whose sudden death had become known during the course of the meeting, which was then terminated.

LIST OF PAPERS,

BEARING UPON THE ZOOLOGY, BOTANY, AND PREHISTORIC ARCHÆOLOGY OF THE BRITISH ISLES, ISSUED DURING 1923.[1]

By T. SHEPPARD, M.Sc., F.G.S., *The Museum, Hull.*

Zoology.

ANON. Colour Variation in a Sea Anemone. *Ann. Mag. Nat. Hist.* May, p. 615. [Abs.] *Scot. Nat.* May, p. 84.
—— American Gooseberry Mildew and Black Currant Mite Order, 1912. 1*st Ann. Rep. Minis. Agric. N. Ireland*, p. 43.
—— Bee Pest Prevention Act, 1908, *tom. cit.*, p. 45.
—— Report of Meetings, 1922. *Hist. Berwicks. Nat. Club*, pp. 364-388.
—— Reports of Meetings, 1923, *tom. cit.* Vol. XXV., pt. I., pp. 25-58.
—— Falcons of Great Orme's Head. *Bird Notes and News.* Vol. X., No. 7, p. 97.
—— Wild Birds Protection Bill, *tom. cit.*, pp. 99-103.
—— Account of the Annual and General Meetings. *Ann. Rep. Bristol Nat. Soc.* Vol. V., pt. v., pp. 238-242.
—— Song-periods as Observed in Ireland. *Brit. Birds.* Jan., pp. 222-223.
—— Obituary: John Lewis James Bonhote, *tom. cit.* Jan., pp. 224-225.
—— Obituary: William Evans, *tom. cit.* Jan., pp. 225-226.
—— Recovery of Marked Birds, *tom. cit.* Apr., pp. 300-305.
—— Additions and Corrections to the Practical Handbook of British Birds and to the Hand-List of British Birds, *tom. cit.* June, pp. 2-4.
—— Recovery of Marked Birds, *tom. cit.* Sept., pp. 77-81.
—— Annual General Meeting [Report]. *Trans. Caradoc and S.V. Field Club.* Mar., pp. 33-51.
—— Field Meetings [Reports], *tom. cit.* Mar., pp. 52-80.
—— Caldey Island: Ravens and Puffins, 1922. *Trans. Carmarthenshire Antiq. Soc.* Pt. XLI., p. 32.
—— Sectional Secretaries' Reports. Zoological Section. *Chester Soc. Nat. Sci.* 52*nd Ann. Rep.*, pp. 11-16.
—— Proceedings of the Conchological Society of Great Britain and Ireland. *Journ. Conch.* Jan., pp. 25-30; July, pp. 53-56; Dec., p. 96.
—— White-headed Blackbird and some others. *Country Life.* Apr. 21, p. 550.
—— Rare Birds in South Devon, *tom. cit.* May 5, p. 622.
—— Sea Birds at Home, *tom. cit.* June 2, pp. 741-743.
—— London Starling and its Work, *tom. cit.* June 9, p. 833.
—— Ravens in South Devon, *tom. cit.* June 16, p. 867.
—— Habits of Trout and Peal, *tom. cit.* July 14, p. 64.
—— Bald Blackbird, *tom. cit.* June 23, p. 901.
—— White-tailed Thrush, *tom. cit.* June 23, p. 901.
—— Effect upon Bird Life of the Cutting Down of Forests, *tom. cit.* July 28, p. 128.
—— Blackbirds and Garden Peas, *tom. cit.* Sept. 1, p. 294.
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